COLLEGE OF ENGINEERING

ADMINISTRATION

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Michael S. Isaacson, associate dean for research, graduate studies and professional education

vacant, associate dean for professional development

Deborah Cox, assistant dean for student services

Cathy Long, assistant dean for administration

Marsha Pickens, assistant dean for alumni affairs and development

Teresa Jordan, associate dean for undergraduate programs

FACILITIES AND SPECIAL PROGRAMS

Most of the academic units of the College of Engineering are on the Joseph N. Pew, Jr. Engineering Quadrangle. Facilities for the School of Applied and Engineering and Physics are located in Clark Hall on the College of Arts and Sciences campus, and facilities for the Department of Biological and Environmental Engineering are centered in Riley-Robb Hall on the campus of the New York State College of Agriculture and Life Sciences.

Special university and college facilities augment the laboratories operated by the various engineering schools and departments, and special centers and programs contribute to opportunities for study and research.

Cornell programs and centers of special interest in engineering include the following:

Center for Applied Mathematics. A cross-disciplinary center that admininsters a graduate program.

Center for Nanoscale Systems in Information Technologies. A National Science Foundation Nanoscience and Technology Center whose mission is to explore new methods for creating nanoscale devices for use in information technologies. The facilities for this center are distributed between Clark Hall and the Engineering Quadrangle.

Center for Radiophysics and Space Research. An interdisciplinary unit that facilitates research in astronomy and the space sciences.

Center for Theory and Simulation in Science and Engineering. A supercomputer facility used for advanced research in engineering and the physical and biological sciences.

Cornell High Energy Synchrotron Source (CHESS). A high-energy synchrotron radiation laboratory operated in conjunction with the university's high-energy storage ring. Current research programs at CHESS are in areas of structural biology, chemistry, materials science, and physics.

Cornell Nanofabrication Facility (part of the National Science Foundation funded National Nanofabrication Users Network). A center that provides equipment and services for research in the science, engineering, and technology of nanometer scale structures for electronic, chemical, physical, and biological applications.

Cornell Waste Management Institute. A research, teaching, and extension program within the Center for Environmental Research that addresses the environmental, technical, and economic issues associated with solid waste; one facility sponsored by the institute is the Combustion Simulation Laboratory in the Sibley School of Mechanical and Aerospace Engineering.

Institute for the Study of the Continents. An interdisciplinary organization that promotes research on the structure, composition, and evolution of the continents.

W. M. Keck Foundation in Nanobiotechnology. Facilities of this program include tools for nanoscale diagnostics of biomaterials.

Laboratory of Plasma Studies. A center for research in plasma physics.

Cornell Center for Materials Research. An interdisciplinary facility with substantial support from the National Science Foundation, providing sophisticated scientific measurement and characterization equipment for materials research.

National Astronomy and Ionosphere Center. The world's largest radio-radar telescope facility, operated by Cornell in Arecibo, Puerto Rico.

National Earthquake Engineering Research Center. A facility recently established by the National Science Foundation and a group of universities in New York State to study response and design of structures in earthquake environments.

Nanobiotechnology Center. A National Science Foundation Science and Technology Center whose mission is to develop nanoscale tools for use in the life sciences. The facilities of this center are distributed between Clark Hall, Kimball Hall and the Biotechnology Center.

National Institutes of Health/National Science Foundation Developmental Resource in Biophysical Imaging and Optoelectronics. A resource that develops novel measurement and optical instrumentation for solving biophysical problems.

Power Systems Engineering Research Center. A National Science Foundation cooperative center between university and industry in which research is centered on power systems and infrastructure networks.

Program of Biomedical Engineering. A cross-disciplinary field that administers the graduate field of Biomedical Engineering.

Program of Computer Graphics. An interdisciplinary research center that operates one of the most advanced computer-graphics laboratories in the United States.

Program on Science, Technology, and Society. A cross-disciplinary unit that sponsors courses and promotes research on the interaction of science, technology, and society.

The programs listed on this page are sponsored by College of Engineering units and several are industry affiliated.

DEGREE PROGRAMS

Cornell programs in engineering and applied science lead to the degrees of Bachelor of Science, Master of Engineering (with field designation), Master of Science, and Doctor of Philosophy.

General academic information concerning the Bachelor of Science degree is given here under the heading "Undergraduate Study." Curricula for major studies are described under the various academic areas.

Programs leading to the Master of Science and Doctor of Philosophy degrees are administered by the Graduate School. They are described in the *Announcement of the Graduate School* and the special announcement *Graduate Study in Engineering and Applied Science*. The professional Master of Engineering programs and cooperative programs with the Johnson Graduate School of Management are described below.

UNDERGRADUATE STUDY

Bachelor of Science (B.S.) degrees are offered in the following areas:*

Biological Engineering†

Chemical Engineering

Civil Engineering

College Program

Computer Science

Electrical and Computer Engineering

Engineering Physics

Earth and Atmospheric Sciences

Materials Science and Engineering

Mechanical Engineering

Operations Research and Engineering

Students in the College of Engineering begin their undergraduate studies in the Common Curriculum, which is administered by the faculty members of the College Curriculum Governing Board (CCGB) through the associate dean for undergraduate programs and Engineering Advising. Subsequently most students enter *field* programs, which are described separately for each academic area. Criteria for entrance into the field programs are described in the section titled "Affiliation with a Field Program." Alternatively students may enter the *College Program* (described below), which permits them to pursue a course of study adapted to individual interests.

Students interested in bioengineering may arrange a suitable curriculum through the bioengineering option, the bioengineering minor, the biomedical engineering minor or the College Program. Students interested in supplementing their field program with formal study in another traditional area of engineering may wish to consider one of the engineering minors offered by the college. Information about both the bioengineering option and engineering minors is available in Engineering Advising, 167 Olin Hall. Students interested in environmental engineering and science may pursue the environmental option offered by the School of Civil and Environmental Engineering and the Department of Biological and Environmental Engineering, or the science of earth systems (SES) option offered by the Department of Earth and Atmospheric Sciences.

*Biological engineering, chemical engineering, civil engineering, electrical engineering, engineering physics, materials science and engineering, mechanical engineering, and operations research and engineering are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology.

†To major in biological engineering students normally enroll in the College of Agriculture and Life Sciences for the first three years, and jointly in that college and the College of Engineering for the final year. Students initially enrolled in the College of Engineering, however, may affiliate with the field of biological and environmental engineering and complete the degree solely within that college.

Requirements for Graduation

To receive the Bachelor of Science degree, students must meet the requirements of the Common Curriculum, as set forth by the College of Engineering, including the requirements of the field program, as established by the school or department with which they become affiliated. Students must meet the Common Curriculum as explained below. (Further explanation of the revised Common Curriculum and field flow charts are provided in the 2002–2003 edition of *The Engineering Undergraduate Handbook*.)

Course Category	*Credits*
1) Mathematics	16
2) Physics (depending on field)	8–12
3) Chemistry (depending on field)	4–8
4) First-Year writing seminar*	6
5) Computer programming†	4
6) Engineering distribution (3 courses)	
a. One Introduction to Engineering (ENGRI)	3
b. Two other engineering distribution courses (ENGRD)	6
7) Liberal studies distribution (6 courses min.)	18 (min.)
8) Approved electives	6
9) Field program	
a. Field required courses	30 cr. min.
b. Field approved electives	9
c. Courses outside the field	9

*One writing-intensive technical course or a course in technical or scientific writing must also be taken; this course may simultaneously satisfy some other requirement.

†One approved course in computing applications must also be taken; this course may simultaneously satisfy some other requirement, such as an engineering distribution course, an approved elective, or a field program course.

From 123 to 133 credits are required for graduation; the specific number of required credits vary depending on which field program is chosen (see field curricula for specific field requirements). Two terms of physical education must be taken in the freshman year and students must demonstrate proficiency in swimming to satisfy a university requirement.

Mathematics

The normal program in mathematics includes MATH 191 (or 190), 192, 293, and 294. Every student must attain a grade of at least C- in MATH 191 (or 190), 192, 293, and 294, or other courses that may be approved as substitutes for these courses. If this requirement is not met the first time a course is taken, the course must be repeated immediately and a satisfactory grade attained before the next course in the sequence may be taken. Failure to achieve at least a C- the second time around will generally result in withdrawal from the engineering program. Courses that are taken a second time in order to meet this requirement do not yield additional credit toward a degree.

Physics

The normal program in physics includes PHYS 112, 213, and 214 or the corresponding honors courses (PHYS 116, 217, and 218). Engineering students are required to have attained a minimum grade of C- in MATH 191 or equivalent before taking PHYS 112. *The same minimum grade is required in each subsequent mathematics course before taking the physics course for which it is a prerequisite (e.g., C- in MATH 192 before taking PHYS 213, or C- in MATH 293 before taking PHYS 214). Students in the field of BEE, CHEME, CEE, COM S, EAS (geoscience and SES options), or OR&E may substitute CHEM 208 for PHYS 214.

Chemistry

CHEM 211 or 207 is required for all students.

CHEM 211 is a course designed for students who do not intend any further study in chemistry. Typically, CHEM 211 is taken during the freshman year, but students who wish to complete the physics program (PHYS 112, 213, and 214) first may postpone CHEM 211 until the sophomore year.

In general, students intending to affiliate with the following departments and schools usually take CHEM 211: Applied and Engineering Physics, Computer Science, Electrical and Computer Engineering, Materials Science and Engineering, Mechanical and Aerospace Engineering, and Operations Research and Industrial Engineering. Students considering Chemical Engineering must take CHEM 207 in the fall of their freshman year, to be followed by CHEM 208 in the spring term. All students considering the environmental option in Civil Engineering, the science of earth systems option in Earth and Atmospheric Sciences, or a health-related career such as medicine, should take the CHEM 207–208 sequence.

First-Year Writing Seminars

Each semester of their freshman year, students choose a First-Year Writing Seminar from among more than one hundred courses offered by over thirty different departments in the humanities, social sciences, and expressive arts. These courses offer the student practice in writing English prose. They also assure beginning students the benefits of a small class.

Technical Writing

The ability to communicate is essential to successful professional practice. In addition to taking two first-year writing seminars, engineering students must have a significant amount of instruction and practice in technical or scientific writing. They can fulfill the college's technical-writing requirement by a) enrolling in an Engineering Communications course (e.g., ENGRC 335 or ENGRC 350), b) enrolling in selected courses in the Department of Communication (COMM 260, 263, or 352), or in an approved writing-intensive engineering course. The third option includes the following writing intensive courses:

- BEE 489
- BEE 493 (with coregistration in BEE 450 or BEE 473)
- ENGRD/A&EP 264
- CHEME 432
- M&AE 427
- MS&E 403–404
- MS&E 405–406

For information on fulfilling the technical-writing requirement by doing a writing-intensive Co-op, contact Engineering Professional Programs, 201 Carpenter Hall, or the Engineering Communications Program, 465 Hollister Hall.

Computing

In either the first or second term of their freshman year, students normally take COM S 100, Introduction to Computer Programming. Before graduation they must take an additional course with a significant amount of computing applications; this course may also be used to meet another graduation requirement. Courses that satisfy this requirement are BEE 453, BEE 475, ENGRD/COM S 211, ENGRD/COM S 322, ENGRD/CEE 241, ENGRD/A&EP 264, ECE 423, M&AE 470, M&AE 479, M&AE 423, M&AE 575, and M&AE 578. The recommended choice for students intending to enter the field program in Engineering Physics is ENGRD 264; in Chemical Engineering, ENGRD 211, 322, or 241; in Civil Engineering, ENGRD 241; in Computer Science, ENGRD 211; in Electrical and Computer Engineering, ENGRD 211; in Mechanical Engineering, M&AE 470, M&AE 479, M&AE 575, or M&AE 578; and in Operations Research and Engineering, ENGRD 211.

Engineering Distribution

Three engineering distribution courses (nine credits) are required. One course must be an Introduction to Engineering Course (designated by ENGRI) to be taken by the student during their freshman year. The Introduction to Engineering course will introduce students to the engineering process and provide a substantive experience in an open-ended problem solving context. See the Introduction to Engineering Course listing for current course offerings.

The other two distribution courses must be selected from two different categories listed below. A student may use any one of the possible substitutions described.

1) *Scientific computing*
   ENGRD 211, Computers and Programming
   ENGRD 241, Engineering Computation
   ENGRD 321, Numerical Methods in Computational Molecular Biology
   ENGRD 322, Introduction to Scientific Computation
2) *Materials science*
   ENGRD 261, Introduction to Mechanical Properties of Materials
3) *Mechanics*
   ENGRD 202, Mechanics of Solids
   ENGRD 203, Dynamics

Students in the field program in Engineering Physics may substitute A&EP 333 for ENGRD 203.

4) *Probability and statistics*
   ENGRD 270, Basic Engineering Probability and Statistics

Students in the field program in Electrical and Computer Engineering may substitute ECE 310 with ENGRD 270. Students in the field program in Engineering Physics may substitute ECE 310 or MATH 471 for ENGRD 270. Students in the field programs in Civil Engineering and Biological Engineering may substitute CEE 304 for ENGRD 270.

5) *Electrical sciences*
   ENGRD 210, Introduction to Circuits for Electrical and Computer Engineers
   ENGRD 230, Introduction to Digital Systems
   ENGRD 264, Computer-Instrumentation Design
6) *Thermodynamics and energy balances*
   ENGRD 219, Mass and Energy Balances
   ENGRD 221, Thermodynamics
7) *Earth and life sciences*
   ENGRD 201, Introduction to the Physics and Chemistry of the Earth
   ENGRD 250, Engineering Applications in Biological Systems
8) *Biology and chemistry*
   A&EP 252/ENGRD 252, The Physics of Life
   BIO G 101 and 103, Biological Sciences, Lecture and Laboratory
   BIO G 105, Introductory Biology
   BIO G 107, General Biology (summer only)
   CHEM 389, Physical Chemistry I

Some fields require a specific engineering distribution course as a prerequisite for the upperclass course sequence. These requirements are:

Biological and Environmental Engineering: ENGRD 202

Chemical and Biomolecular Engineering: ENGRD 219

Civil Engineering: ENGRD 202

Computer Science: ENGRD 211 (co-enrollment in COM S 212 strongly recommended)

Electrical and Computer Engineering: ENGRD 230

Earth and Atmospheric Sciences: ENGRD 201

Materials Science and Engineering: ENGRD 261

Mechanical Engineering: ENGRD 202

Operations Research and Engineering: ENGRD 270

Liberal Studies Distribution

A minimum of six required liberal studies courses (totaling at least 18 credits) may be chosen from approved courses in four categories: (a) humanities or history, (b) social sciences, (c) foreign languages, and (d) expressive arts. (No First-Year Writing Seminar may be used to meet the liberal studies requirement.)

- At least two courses must be chosen from category (a).
- At least two courses in either category (a), (b), or (d) must be from the same field of study and in the same category. One of these courses must be at or above the 200-level or both courses can be at the 100 level only if one is the prerequisite of the other.

Following each category is a list of approved courses. Every effort has been made to keep the lists up to date, but errors sometimes occur. Students who wish to use a course that seems to fit the category description but is not listed should contact Engineering Advising.

a) Humanities or History

American Studies 101, 201, 202

Architecture 131, 132, 181, 182, 382

Art 317, 318

Africana Studies 202, 204, 205, 211, 280, 285, 304, 310, 361, 370, 381, 404, 422, 425, 431, 432, 435, 455, 475, 483

Anthropology 290, 451, 452, 453, 455

Archeology (courses in Old World Archeology and 493)

Asian Studies (courses in Asian art, literature, religion, or cultural history)

Biology and Society 205, 206

Classics (all courses except 285, 356, 360, 361, and language courses)

Collective Bargaining, Labor Law, and Labor History 100, 101, 384, 385, 386, 482, 488

Communication 426

Comparative Literature (all courses)

Economics 323, 324, 325, 326, 417

Engineering ENGRG 198, 250, 298, 360

English (all courses except ENGL 285 and writing courses, whose numbers end in the 80s; e.g., 288, 289, 382, etc.)

French Literature (all courses)

German Literature (all courses)

History (all courses)

History of Art (all courses except ART H 200)

Industrial and Labor Relations Interdepartmental Course 451

International and Comparative Labor Relations 430

Italian Literature (all courses)

Jewish Studies 274, 351, 352

Labor Economics 448

Linguistics 109

Music (only introductory, music theory, music history, and digital music courses)

Natural Resources 407

Near Eastern Studies (courses listed under history, civilization, or literature)

Philosophy (all courses except courses in logic and PHIL 383)

Religious Studies 101

Russian Literature (all courses)

Science and Technology Studies 201, 205, 206, 233, 250, 281, 282, 283, 287, 292, 355, 360, 433, 444, 447, 525, 687, 711

Spanish Literature (all courses)

Theater Arts (only courses in Theater Studies, film analysis, and history)

Women's Studies 227, 238, 251, 264, 273, 307, 341, 348, 363, 365, 366, 374, 390, 404, 406, 408, 426, 433, 444, 445, 451, 455, 474, 493

b) Social Sciences

Africana Studies 171, 172, 191, 220, 231, 271, 280, 290, 300, 301, 311, 380, 410, 420, 451, 459, 478, 479

Agricultural Economics (ARME) 100, 250, 430, 431, 432, 450, 451, 464

Anthropology (all courses except 101 and courses in Biological and Ecological Anthropology)

Archeology (all courses except those in Methodology and Technology)

Architecture 342

Asian American Studies 110

Asian Studies (courses in Asian anthropology, economics, government, linguistics, or sociology)

Biology and Society 201, 301, 406, 407

City and Regional Planning 100, 101, 314, 361, 382, 404, 442

Communication 116, 120, 240, 410, 420

Design and Environmental Analysis 150, 250

Economics (all courses except 315, 317, 318, 319, 320, 321, 326. Engineering students should generally take ECON 301–302 and *not* 101–102, unless they have had no calculus.)

Education 210, 212, 271, 311, 317, 322, 360, 413, 477

Government (all courses)

Human Development and Family Studies (all courses)

International and Comparative Labor Relations (all courses)

Labor Economics (all courses except 345 and 448)

Linguistics (all courses)

Natural Resources 350, 400

Organizational Behavior (all courses)

Policy Analysis and Management (all courses except 305, 323, 326, 371, 424, 425, 606, and 607)

Psychology (all courses *except* 111, 223, 307, 322, 324, 326, 332, 350, 361, 396, 422, 425, 426, 429, 465, 470, 471, 472, 473, 475, 476, 478, 479, 480, 491, 492)

Rural Sociology (all courses)

Science and Technology Studies: 311, 350, 360, 390, 391, 401, 407, 411, 427, 453, 483, 490, 645, 664, 700

Sociology (all courses)

Textiles and Apparel 245

Women's Studies 210, 218, 220, 238, 244, 277, 281, 297, 305, 321, 353, 362, 365, 366, 372, 406, 408, 425, 428, 438, 450, 454, 463, 468, 479, 480, 493

c) Foreign Language

This category includes all foreign language (non-literature) courses; if two or more foreign language courses are used to fulfill part of the liberal studies requirement, they must be a sequence of courses in the same language. The rules for placement and advanced placement credit in languages are those of the College of Arts and Sciences. Speakers of languages other than English may obtain up to six advanced placement credits equal to two courses according to these rules.

d) Expressive Arts

Africana Studies 303, 425, 430

Art (studio courses)

Biological Sciences 208, 209

Communications (all courses except 116, 120, 314, 410, 416, 420, 426, 465)

Design and Environmental Analysis 101, 102

Engineering (all Engineering Communications courses, which are designated ENGRC)

English (expository and creative writing courses, whose numbers end in the 80's, e.g., 288, 289, 382, etc.)

Floriculture (courses in Freehand Drawing and Scientific Illustration)

Industrial and Labor Relations 452

Music (courses in musical performance, musical organizations and ensembles; three one-credit courses equals one course)

Science and Technology Studies 352

Theater Arts (all courses except those listed in category (a) above)

Electives

- Approved electives—six credits required (approved by the academic adviser)

Because these courses should help develop and broaden the skills of the engineer, advisers will generally accept the following as approved electives:

1. One Introduction to Engineering course (ENGRI).
2. Engineering distribution courses.
3. Courses stressing written or oral communication.
4. Upper-level engineering courses.
5. Advanced courses in mathematics.
6. Rigorous courses in the biological and physical sciences.
7. Courses in business, economics, or language (when they serve the student's educational and academic objectives).
8. Courses that expand the field program or another part of the curriculum (Note: No ROTC courses may be used as approved electives unless they are co-listed by an academic department.)

- Field approved electives—nine credits (approved by engineering field program faculty and field faculty advisers). Students should refer to the field program curricula for descriptions of courses that meet this category.
- To ensure breadth of engineering studies, field programs will also include nine credits of courses outside the field.

Social Issues of Technology

It is important for engineers to realize the social and ethical implications of their work. Consequently, in selecting their humanities, social sciences, and approved electives, students are urged to consider courses listed in the "Science and Technology Studies" undergraduate area of concentration (see Interdisciplinary Centers and Programs section). These courses may provide students with an important perspective on their studies and their future careers.

Student Success Center

From the time students enter the college as freshmen until they are affiliated with a major field (*normally* prior to the second semester of the sophomore year), they are under the administration of Engineering Advising, which implements the academic policies of the College Curriculum Governing Board. Engineering Advising, Engineering Minority and Women's Program's Programs, and Learning Initiatives for Future Engineers (LIFE) comprise the Student Success Center. The Center serves as the primary resource center for undergraduate students in the college, offering general advising and counseling, tutoring, instructional support and networking opportunities.

Freshman Year Requirements

By the end of the freshman year, engineering students are expected to have completed (or received credit for) the following core requirements:

- MATH 191 (or 190) and MATH 192
- Two of the following: CHEM 211, 207, 208, PHYS 112, 213, 214*
- COM S 100
- Two First-Year Writing Seminars
- One Introduction to Engineering course (ENGRI designation)
- Two Physical Education courses

*Students with an interest in pre-med (or other health-related careers), Chemical Engineering, the environmental option in Civil Engineering, or the science of earth systems option in Earth and Atmospheric Sciences should enroll in the CHEM 207–208 sequence during their freshman year.

Affiliation with a Field Program

Students must apply for affiliation with a field program during the first term of their sophomore year, although earlier affiliation may be granted at the discretion of the field. This is done by visiting the undergraduate field consultant's office in the field of their choice and completing the Application for Field Affiliation form. To affiliate with a field program, students must (1) have a 2.0 cumulative grade point average and (2) have satisfied the field's course and grade requirements as specified below:

(Please note that fields may impose alternative affiliation requirements for students applying for affiliation later than the first semester of the sophomore year.)

Field Program	*Courses and Minimum Grade Requirements*
Biological and Environmental Engineering	No more than one grade below C- in mathematics and science courses and BEE 151 or equivalent
Chemical and Biomolecular Engineering	No more than one grade below C- in chemistry, mathematics, physics, or chemical engineering courses and a 2.2 GPA in mathematics, science, and chemical engineering courses
Civil Engineering	A 2.0 GPA in all engineering and science courses and a grade of C- or better in ENGRD 202 (for students in the environmental option who do not take ENGRD 202 prior to affiliation, a grade of C- or better in CHEM 208 is required)
Computer Science	Completion of MATH 293, COM S 211, 212, and 280; a grade of C or better in Com S 211, 212, and 280, with the overall average of all COM S courses above COM S 100 being 2.7 or better A grade of C or better in all required math courses beyond introductory calculus (i.e. MATH 190, 191, or 193), with the overall average of these courses being 2.7 or better. Courses used in the affiliation GPA computations may be repeated if the original course grade was below a C. The most recent grade will be used for all repeated courses. Qualifying courses must be taken at Cornell NOTE: for complete affiliation requirements, visit www.cs.cornell.edu/ugrad
Electrical & Computer Engineering	Be in good academic standing in the College of Engineering. Must have completed with a grade of C+ or better in MATH 293, PHYS 213, and either ENGRD/ECE 210 (4 credits) or ENGRD 230 Must have an average GPA of at least 2.5 in the following courses if completed: MATH 192, 293, 294, PHYS 213, ENGRD 211, 230, ECE/ENGRD 210 (4 credits)

Engineering Physics	A grade of B- or better in all required mathematics and physics courses
Geological Sciences	Good academic standing in the College of Engineering
Materials Science & Engineering	A grade of C- or better in all physics and chemistry courses and a grade of C or better in ENGRD 261
Mechanical Engineering	A grade of C- or better in mathematics and science courses and ENGRD 202
Operations Research & Engineering	A grade of C- or better in MATH 191, 192, ENGRD 270 and a 2.0 GPA in all mathematics, science, and engineering courses (both overall and in the term immediately prior to affiliation)

Students must be affiliated or conditionally affiliated by the end of their fourth semester or they will be withdrawn from the College of Engineering, unless allowed to participate in a terminal semester.

SPECIAL PROGRAMS

Dual Degree Option

A special academic option, intended for superior students, is the dual degree program, in which both a Bachelor of Science and either a Bachelor of Arts or Bachelor of Fine Arts degree can be earned in about five years. Students registered in the College of Engineering, the College of Arts and Sciences, or the College of Architecture, Art, and Planning may apply and, after acceptance of their application, begin the dual degree program in their second or third year. Those interested should contact the appropriate coordinators of dual degree programs at the following locations: 55 Goldwin Smith Hall (for Arts and Sciences), 135 East Sibley (for Architecture, Art, and Planning); and the Director of Engineering Advising, 167 Olin Hall.

Double Major in Engineering

The Double Major option, which makes it possible to develop expertise in two allied fields of engineering, generally requires at least one semester beyond the usual four years. Students affiliate with one field following normal procedures and then petition to enter a second field before the end of their junior year. All the requirements of both fields must be satisfied. Further information is available from Engineering Advising, 167 Olin Hall, and the individual field consultant offices.

College Program

Individually arranged courses of study under the College Program are possible for those students whose educational objectives cannot be met by one of the regular field programs. Often the desired curriculum is in an interdisciplinary area. Each program is developed by the student in consultation with faculty advisers and must be approved by the College Program Committee, which is responsible for supervising the student's work.

Students should apply to enter the College Program during the sophomore year. A student should seek assistance in developing a coherent program from professors in the proposed major and minor subject areas. If approved, the program is the curricular contract to which the student must adhere.

Every curriculum in the College Program, with the exception of certain faculty-sponsored programs, must comprise an engineering major and an educationally related minor. The major may be in any subject area offered by schools or departments of the college; the minor may be in a second engineering subject area or in a logically connected nonengineering area. The combinations must clearly form an engineering education in scope and in substance and should include engineering design and synthesis as well as engineering sciences. In addition to 48 credits in the major and minor subjects, including at least 32 credits in engineering courses, each program includes the normally required courses in humanities and social sciences and approved electives.

Further information about the College Program may be obtained from the Director of Engineering Advising, 167 Olin Hall.

Important note: because no single standardized curriculum exists, the College Program is not accredited. College Program students who intend to seek legal licensing as a Professional Engineer should be aware that this non-accredited degree program will require additional education, work, and/or experience to qualify for eligibility to take the Fundamentals of Engineering examination, and may affect acceptance into engineering graduate programs.

Engineering Minors

The Engineering Minor is a supplement to the regular bachelor's degree programs in the college, including the College Program, and recognizes formal study of a particular technical subject area in engineering normally outside the student's major. Therefore, it may be necessary for some students choosing to complete the requirements for an engineering minor to spend more than the traditional eight semesters to complete their studies at Cornell. In many cases, however, courses fulfilling minor requirements may also satisfy other degree requirements (e.g., distribution courses, approved electives, or field-approved electives). Students undertaking a minor are expected to complete the requirements during the time of their continuous undergraduate enrollment at Cornell.

To complete an engineering minor, an undergraduate engineering student must

- be enrolled in a major field program that approves the participation of its affiliates in the desired minor.
- successfully complete all the requirements for a bachelor of science degree in engineering.
- satisfactorily complete six courses (18 credit minimum) as stipulated in a college-approved minor.

Students may apply for certification of an engineering minor at any time after the necessary coursework has been completed in accordance with published standards. Students who receive certification in an approved engineering minor will be recognized by means of an official notation on their Cornell transcript following graduation.

The College of Engineering currently offers minors in the following areas (offering departments are indicated in parentheses):

Applied Mathematics (T&AM)

Biological Engineering (BEE)

Biomedical Engineering (T&AM)

Civil Infrastructure (CEE)

Computer Science (COM S)

Electrical and Computer Engineering (ECE)

Engineering Management (CEE)

Engineering Statistics (OR&IE)

Environmental Engineering (BEE/CEE)

Geological Sciences (EAS)

Industrial Systems and Information Technology (OR&IE)

Information Science (COM S)

Materials Science and Engineering (MS&E)

Mechanical Engineering (M&AE)

Operations Research and Management Science (OR&IE)

Additional information on specific minors can be found in the departmental sections of this publication, The *Engineering Undergraduate Handbook*, the undergraduate field office of the department offering the minor, and the Student Success Center.

Minor in Applied Mathematics

To complete the minor, the student must take at least six (6) courses beyond MATH 294, to be chosen as follows:

a) No more than 1 course may be chosen from any one of the groups 1, 2, 3 or 4.

b) At least 3 courses must be chosen from groups 5 and 6.

c) No more than one 200-level course may be chosen.

d) No more than 1 course may be chosen which is offered by the student's Major Department.

1. Analysis

TAM 310	Advanced Engineering Analysis I
MATH 311	Introduction to Analysis
MATH 420	Differential Equations and Dynamical Systems
AEP 321	Mathematical Physics I

2. Computational methods

CS 322	Introduction to Scientific Computation
CEE 241	Engineering Computation
ORIE 320	Optimization I

3. Probability and Statistics

ORIE 270	Basic Engineering Probability and Statistics
ORIE 360	Engineering Probability and Statistics II
EE 310	Introduction to Probability and Random Signals
CEE 304	Uncertainty Analysis in Engineering

4. Applications

AEP 333	Mechanics of Particles and Solid Bodies
ChemE 323	Fluid Mechanics
CEE 331	Fluid Mechanics
CEE 371	Structural Behavior
EE 425	Digital Signal Processing
MAE 323	Intro to Fluid Mechanics
MSE 303	Thermodynamics of Condensed Systems

5. Advanced Courses

Only one of the following three may be chosen:

TAM 311	Advanced Engineering Analysis II
MATH 422	Applied Complex Analysis
AEP 322	Mathematical Physics II

Only one of the following two may be chosen:

EE 411	Random signals
ORIE 361	Introductory Engineering Stochastic Processes I

Only one of the following two may be chosen:

CS 381	Introduction to Theory of Computing
CS 481	Introduction to Theory of Computing
CS 482	Introduction to the Design of Algorithms
ORIE 321	Optimization II
ORIE 431	Discrete Models
ORIE 435	Introduction to Game Theory
ORIE 462	Introductory Engineering Stochastic Processes II
EE 522	Nonlinear systems

Only one of the following two may be chosen:

MAE 571	Intermediate Dynamics
TAM 570	Intermediate Dynamics
TAM 578	Nonlinear Dynamics and Chaos

6. Math Courses

Any 300+ level course offered by the Mathematics Department in algebra,

analysis, probability/statistics, geometry or logic, with the following exceptions:

i) MATH 311 or MATH 420, if any course from group 1 is chosen.

ii) MATH 422, if TAM 311 or AEP 322 are chosen from group 5.

Academic Standards: A letter grade of C or better for each course in the minor.

Required Courses

COM S/ENGRD 211 Computers and Programming

COM S 321 Numerical Methods in Computational Biology

or COM S/ ENGRD 322 Introduction to Scientific Computing

or COM S 421 Numerical Analysis

The Bioengineering Option and the Biological Engineering and Biomedical Engineering Minors

Students wishing to apply the concepts and methods of the engineering, computational and physical sciences to living systems or health issues may pursue one of three courses of study:

(1) the bioengineering option, requiring completion of four bioengineering courses (12 credit hours minimum) and one credit hour of Bioengineering Seminar (ENGRG 501). The student will receive official notation on their transcript. Further information is available in Engineering Advising, 167 Olin Hall.

(2) the biological engineering minor, requiring six courses (18 credit hours minimum) including BEE 350, two analysis courses, two application courses and one basic science course. This minor provides the student an opportunity to further their understanding of living systems and the basic transport processes that occur in these systems. Further information is available from the BEE Program Coordinator, 207 Riley-Robb Hall.

(3) the biomedical minor, requiring six courses (18 credit hours minimum) from at least four of five different groups—Introductory Biology, Advanced Biology, Molecular and Cellular BME, BME Analysis of Physiological Systems, BME Applications. Further information is available from the Biomedical Engineering Program coordinator, 270 Olin Hall.

International Programs

All students who plan to study abroad apply through Cornell Abroad; please see the Cornell Abroad program description in the introductory section of Courses of Study.

An international perspective, sensitivity to other cultures, and the ability to read and speak a second language are increasingly important to today's engineers. In keeping with the university goals of internationalizing the curriculum, the College of Engineering encourages students to study or work abroad during their undergraduate years. For further information on these and other opportunities to add an international dimension to your undergraduate education, see the staff in Engineering Advising, 167 Olin Hall. Students who seek advice on obtaining an international co-op work experience should visit the Engineering Cooperative Education and Career Services office, 201 Carpenter Hall.

Engineering Communications Program

The Engineering Communications Program (ECP) provides instruction in the written, oral, and visual presentation of technical and scientific information. Engineering Communications (ENGRC 350) and Communications for Engineering Managers (ENGRC 335) are three-credit seminars that give students a thorough introduction to these areas. These courses use material from the engineering and business workplace, and many assignments are based on actual events and professional situations. Topics covered may include effective teamwork, organizational and ethical issues, and communicating technical information to both technical and non-technical audiences. Classes have lively discussion, and the limited size of sections ensures close attention to individual students' work. Occasionally, instructors offer special courses or independent studies. The three-credit ECP courses fulfill the college's technical-writing requirement (see Requirements for Graduation).

Among its other activities, the ECP works with engineering faculty to integrate communications instruction into writing-intensive technical courses. ECP instructors may give workshops and lectures on relevant communications topics, as well as help to develop assignments, instructional materials, and assessment strategies for written work and oral presentation. The goal of writing-intensive efforts is to strengthen students' understanding of engineering course material while increasing their ability to communicate what they know.

When possible, the ECP gives presentations to student groups on effective writing, oral communication, and teamwork, and it has been involved in innovative educational projects, e.g., Peer Teaching in Engineering, ENGRG 470, a collaborative learning initiative in physics, mathematics, chemistry, and engineering design. The program awards several annual prizes for outstanding writing, oral presentation, and teamwork. For further information, contact the ECP, 465 Hollister Hall.

Engineering Cooperative Education Program

A special program for undergraduates in most fields of engineering is the Engineering Cooperative Education Program, which provides an opportunity for students to gain practical experience in industry and other engineering-related enterprises before they graduate. By supplementing course work with carefully monitored, paid jobs, co-op students are able to explore their own interests and acquire a better understanding of engineering as a profession.

To be eligible, a student must have been enrolled at Cornell for four semesters prior to working, with a cumulative GPA of 2.7 or higher. (Students in Computer Science and Biological and Environmental Engineering are eligible, even though they may not be registered in the College of Engineering.) Applicants are interviewed by representatives of participating employers and select their work assignments from any offers they receive. Those students who are offered assignments and elect to join the program usually take their fifth-term courses at Cornell during the summer following their sophomore year and begin the first co-op work assignment that fall. They return to Cornell to complete term six with their classmates and then undertake a second work assignment with the same employer the following summer. Co-op students return to campus for their senior year and graduate with their class.

Further information may be obtained from the Engineering Cooperative Education and Career Services office, 201 Carpenter Hall.

MASTER OF ENGINEERING DEGREE PROGRAMS

One-year Master of Engineering (M.Eng.) programs are offered in 14 fields. These programs are discussed in this announcement in connection with the corresponding upperclass engineering field programs because the curricula are integrated. Cornell baccalaureate engineering graduates frequently continue their studies in the M.Eng. program, although the program is also open to qualified graduates of other schools. Prospective students should access the Master of Engineering web site (www.engineering.cornell.edu/grad) for program specifics. The M.Eng. degree fields and their academic departments under which they are administered are listed below.

M.Eng. (Aerospace): Mechanical and Aerospace Engineering

M.Eng. (Agricultural and Biological): Biological and Environmental Engineering

M.Eng. (Chemical): Chemical and Biomolecular Engineering

M.Eng. (Civil & Environmental): Civil and Environmental Engineering

M.Eng. (Computer Science): Computer Science

M.Eng. (Electrical): Electrical and Computer Engineering

M.Eng. (Engineering Physics): Applied and Engineering Physics

M.Eng. (Geology): Earth and Atmospheric Sciences

M.Eng. (Materials): Materials Science and Engineering

M.Eng. (Mechanical): Mechanical and Aerospace Engineering

M.Eng. (Engineering Mechanics): Theoretical and Applied Mechanics

M.Eng. (Nuclear): Nuclear Science and Engineering

M.Eng. (OR&IE): Operations Research and Industrial Engineering

M.Eng. (Systems): Systems Engineering

Admission:

Requirements for admission vary by field and prospective students should contact the appropriate field. In general, the standard M.Eng. application requirements include:

- Statement of Purpose
- Complete transcripts from each college or university you have attended
- At least two letters of recommendation
- Graduate Record Examinations (GRE) scores—may not be required by all fields.

Many fields wave the GRE requirement and one of the letters of recommendation for students with Cornell Engineering BS degrees. Students should check with the appropriate field office for specific program requirements. A list of M.Eng. field links and general admission information is posted on the web www.engr.cornell.edu/grad/meng/app.html.

The following M.Eng. Options are offered:

- The Bioengineering Option
- The Financial Engineering Option
- The Manufacturing Option
- The Engineering Management Option
- The Systems Engineering Option

Each option is available to M.Eng. students in specific fields. The Master of Engineering Options web page www.engr.cornell.edu/grad/meng/options.html lists specific details including availability and contact information.

Cooperative Programs with the Johnson Graduate School of Management:

The Lester Knight Scholarship Program is designed to assist and encourage Cornell Engineering students and alumni interested in combining their engineering training with a business degree.

The Knight Scholarship Program offers three options or categories of financial support:

- The Alumni Knight Scholarship Option
- The Undergraduate Knight Scholarship Option
- The Six-Year Knight Scholarship Option

Each program has different qualifications and is open to Cornell engineering students and alumni at different stages of their educational or professional careers. Participation in the Knight Scholarship program requires admission by each respective academic program (M.Eng, MBA) as well as an application to participate in the Knight Scholarship Program. Refer to the Knight Scholarship web site (www.engr.cornell.edu/grad/knight) for program specifics or contact the Office of Research, Graduate Studies, and Professional Education, 146 Olin Hall.

Early Admission Program:

Superior Cornell Students who will have between one and eight credits remaining in their last undergraduate semester may petition the appropriate field representative for early admission to the M.Eng. program.

Program Options:

Cornell's Master of Engineering Program allows students to supplement their field curriculum with a program option. Students who choose a program option enroll in courses that satisfy elective requirements.

ACADEMIC PROCEDURES AND POLICIES

Advanced Placement Credit

The College of Engineering awards a significant amount of advanced placement (AP) credit to entering freshmen who demonstrate proficiency in the subject areas of introductory courses. Students can earn AP credit by receiving qualifying scores on any of the following:

(1) Advanced placement examinations given and scored by the College Entrance Examination Board (CEEB);

(2) General Certificate of Education (GCE) Advanced ("A") Level Examinations;

(3) International Baccalaureate (IB) Higher Level Examinations; or

(4) Cornell's departmental placement examinations, given during orientation week prior to the beginning of fall-term classes.

Advanced placement credit is intended to permit students to develop more challenging and stimulating programs of study. Students who receive AP credit for an introductory course may use it in three different ways.

1) They may enroll in a more advanced course in the same subject right away.

2) They may substitute an elective course from a different area.

3) They may enroll in fewer courses, using the AP credit to fulfill basic requirements.

Acceptable Subjects and Scores for CEEB or Cornell Departmental AP Exams

The most common subjects for which AP credit is awarded in the College of Engineering, and the scores needed on qualifying tests, are listed below. AP credit is awarded only for courses that meet engineering curriculum requirements.

Mathematics: MATH 191 (or 190), 192, 293, and 294 are required.

First-term math (MATH 191). AP credit may be earned by:

- a score of 3, 4, or 5 on the CEEB BC exam, or
- a score of 5 on the CEEB AB exam, or
- a passing score on the Cornell departmental exam for first-term math.

First-year math (through MATH 192). AP credit may be earned by:

- a passing score on the Cornell departmental exam for first-year math.

Physics: PHYS 112 and 213 are required.

PHYS 112. AP credit may be earned by:

- a score of 4 or 5 on the mechanics portion of the CEEB C exam, or
- a score of 5 on the CEEB B exam *only* if the student has at least one semester of AP or transfer credit in first-term mathematics at the time of matriculation, or
- a passing score on the Cornell departmental exam for PHYS 112.

Note: Students who have received credit for PHYS 112 **may not** enroll in PHYS 213 unless concurrently enrolled in MATH 293.

PHYS 213. Students receiving a 5 on the Electricity and Magnetism portion of the C exam may choose to accept AP credit for PHYS 213 or placement in PHYS 217 with no AP credit for PHYS 213. For advice or more information contact the departmental representative at 607 255–6016.

Chemistry: CHEM 207 or CHEM 211 is required.

CHEM 207 or CHEM 211. AP credits may be earned by:

- a score of 5 on the CEEB AP exam, or
- a passing score on the Cornell departmental exam for Chemistry.

Note: students who are successful in obtaining AP credit for CHEM 207 and who are considering majors in Chemical Engineering or Materials Science and Engineering should consider enrolling in CHEM 215. Those who are offered AP credit for CHEM 207 and then elect to take CHEM 215 will also receive academic credit for CHEM 207. You may want to discuss this option with your faculty adviser.

Computing: COM S 100 is required. AP credit may be earned by:

- a score of 5 on the CEEB A or a score of 4 or 5 on the AB exam, or
- a passing score on the Cornell departmental exam for COM S 100.

Biology: Biology is not required of engineering students, although it is a popular option as an elective, especially for students who intend to pursue health-related careers. AP credit may be earned as follows:

- eight credits will be offered to students who receive a 5 on the CEEB AP exam;
- six credits will be offered to students who receive a 4 on the CEEB AP.

Those who want to study more biology should contact the Office of Undergraduate Biology, 200 Stimson Hall, to discuss proper placement.

First-Year Writing Seminar: Two First-Year Writing Seminars (for a total of six credits) are required.

- AP credit for one First-Year Writing Seminar may be earned by a score of 5 on either of the CEEB AP English exams.

Students who earn a score of 4 on the AP English Literature and Composition exam will be offered three credits which may be applied toward the Humanity/History category (a) of the Liberal Studies distribution requirement. Students who earn a score of 4 on the AP English Language and Composition exam will be offered three credits which may be applied toward the Expressive Arts (d) category of the Liberal Studies distribution requirement.

Liberal Studies Distribution: Six courses beyond two First-Year Writing Seminars are required. Students may earn AP credit toward the liberal studies distribution by taking College Entrance Examination Board (CEEB) AP tests. AP credit earned in the humanities or social sciences cannot be used to fulfill the "upper level" liberal studies requirements.

Modern Languages: Students may earn AP credit for competence in a foreign language by taking the College Entrance Examination Board (CEEB) AP test or by taking the Cornell Advanced Standing Examination (CASE). Those who score 4 or 5 on the CEEB AP test are entitled to three credits. In order to qualify for the CASE exam, the student must score at least 650 on a College Placement Test (taken either in high school or at Cornell during Orientation Week). A score of 2 on the CASE entitles the student to three credits, and a score of 3 entitles the students to six credits which are equivalent to two courses. Modern language AP credits may be used to satisfy the foreign language category of the liberal studies distribution, or may meet an approved elective requirement, contingent on discussions with the faculty adviser.

Advanced Placement and Credit for International Credentials

Students who have successfully completed either a General Certificate of Education (GCE) Advanced ("A") Level Examination or an International Baccalaureate (IB) Higher Level Examination may be eligible for advanced placement credit in the College of Engineering as follows:

General Certificate of Education Advanced Level Examination (GCE "A")

Hong Kong Advanced Level examinations and the joint examination for the Higher School Certificate and Advanced Level Certificate of Education in Malaysia and Singapore—principal passes only—are considered equivalent in standard to GCE "A" Levels.

Subject	Marks	Credit
Biology	A or B	8 credits
Chemistry	A	8 credits (CHEM 207 and 208)
	B	4 credits (CHEM 207)
Mathematics	A or B	8 credits (MATH 191/190 and 192)
	C	4 credits (MATH 191/190)
Physics	A or B	4 credits for PHYS 112; 4 additional credits for PHYS 213 are granted to a combination of grades of A or B and a minimum of 8 Advanced Placement (or advanced standing) credits in mathematics.

International Baccalaureate (IB) Higher Level Examination

Subject	Marks	Credit
Biology	7	8 credits
	6	6 credits
Chemistry	6 or 7	4 credits (CHEM 207 or CHEM 211)
Computer Science	6 or 7	4 credits (COM S 100)
Mathematics	6 or 7	8 credits (engineering students must consult with the math department to determine prerequisite for placement in third-semester math course.)
Physics	6 or 7	4 credits (PHYS 112)

Note: Advanced Placement credit based on GCE or IB results may also be awarded for courses that satisfy the liberal studies requirement in the College of Engineering. In such cases, the College of Engineering follows the AP guidelines found earlier in this publication under "General Information."

General Policies for Advanced Placement

The general policies in the College of Engineering governing awards of AP credit are as follows:

1. AP credit will not be offered in any subject area without a documented examination.
2. All AP examinations are normally taken and scored before fall-term classes begin. Students who take CEEB AP tests in high school should have an official report of their scores sent directly to Cornell as soon as possible. Students who have completed either GCE "A" Level or IB Higher Level Examinations must present the original or a certified copy of their examination certificate to Engineering Advising, 167 Olin Hall. Those who wish to take departmental examinations should do so during Orientation Week; permission to take these tests after the start of fall-term classes must be requested in a written petition to the College's Committee on Academic Standards, Petitions, and Credit (ASPAC).

A more detailed description of the college's policies concerning advanced placement credit and its use in developing undergraduate programs may be found in the pamphlet *Advanced Placement and Transfer Credit for First-Year Engineering Students*, which may be obtained from Engineering Advising, 167 Olin Hall.

Transfer Credit for First-Year and Continuing Students

Undergraduate students who have completed courses at recognized and accredited colleges may, under certain conditions, have credits for such courses transferred to Cornell. Such courses must represent academic work in excess of that required for the secondary school diploma and must be documented as such in writing by the secondary institution. Courses deemed acceptable for transfer credit must be equivalent in scope and rigor to courses at Cornell. Transfer credit will not be awarded for courses taken during a semester in which the student is enrolled at Cornell.

- To apply for transfer credit, students must complete and submit a Transfer Credit Form (one form for each request), accompanied by a course description. (Transfer Credit Forms are available from Engineering Advising or the Registrar's Office and should be submitted prior to enrollment.) An official transcript from the offering institution (bearing the institutional seal and registrar's signature) must be sent to the Engineering Registrar's office before official transfer credit will be awarded.
- To apply for transfer credit to satisfy requirements in mathematics, science, engineering courses, or First-Year Writing Seminars, a student must receive approval from the department offering an equivalent course at Cornell. The department certifying the course may require course materials, textbooks used, etc., in addition to the course description before approving the course.
- Departmental approval is not required to apply for transfer credit which satisfies liberal studies distribution requirements. The course will be reviewed for approval by a representative of the Committee on Academic Standards, Petitions, and Credit (ASPAC) in the Engineering Advising Office.
- Cornell does not award credit for courses in which a student has earned a grade of less than C; schools and departments may stipulate a higher minimum grade.
- College courses completed under the auspices of cooperative college and high school programs will be considered for advanced placement credit only if students demonstrate academic proficiency by taking the appropriate AP or Cornell departmental placement

examination, as described in the Advanced Credit section.

- Following matriculation, students may apply up to 18 credits of transfer and/or Cornell extramural credit toward bachelor's degree requirements.
- No more than 72 total transfer credits (combination of those taken both before and after matriculation) may be used to meet graduation requirements.
- Summer session courses taken at Cornell are not considered transfer credit.
- A more detailed description of the college's regulations governing transfer credit may be found in the pamphlet, *Advanced Placement and Transfer Credit for First-Year Engineering Students,* as well as *The Engineering Undergraduate Handbook*, both available from Engineering Advising, 167 Olin Hall.

Transfer credit for Transfer Students

Transfer students may transfer up to 36 credits for each year spent in full-time study at another institution, provided that the courses are acceptable for meeting graduation requirements. Transfer credit is determined by the fields.

Academic Standing

Full-time students are expected to remain in good academic standing. The criteria for good standing changes somewhat as a student progresses through the four years of the engineering curriculum. At all times, the student must be making adequate progress toward a degree, but what this actually means varies from field to field.

Requirements for freshman engineering students to be in good standing at the end of the first semester are as follows. Failure to meet these standards will result in a review by the Committee on Academic Standards, Petitions, and Credit (ASPAC), and the actions of warning, stern warning, required leave of absence, or withdrawal from the College of Engineering may be taken.

1. At least 12 credits passed, including at least two courses from mathematics, science, and/or engineering
2. A C- or better in the mathematics course
3. A semester average of 2.0 or higher
4. No F, U, or INC grades

Requirements for second-semester freshman and first-semester sophomores to be in good standing are as follows. Failure to meet these standards will result in a review by the Committee on Academic Standards, Petitions, and Credit (ASPAC), and the actions of warning, stern warning, required leave of absence, or withdrawal from the College of Engineering may be taken.

1. At least 14 credits passed in courses that meet engineering degree requirements
2. A C- or better in the mathematics course, if one was taken
3. A semester average of 2.0 or higher
4. No F, U, or INC grades

Academic Progress

The total number of credits required for graduation range from 123 to 133, depending on the field program. Therefore, an average semester credit load ranges from approximately 15 to 17 credits.

Because mathematics is pivotal to the study and practice of engineering, students must earn a grade of C- or better in MATH 191 (or 190), 192, 293, and 294. Those who fail to meet this standard are allowed to repeat a course once in the following semester. Failure to achieve at least a C- the second time will generally result in withdrawal from the College of Engineering. Physics and advanced mathematics courses often have mathematics prerequisites, and having to repeat the prerequisite course may delay progress in the physics and mathematics curricula.

Dean's List

Dean's List citations are presented each semester to engineering students with exemplary academic records. The criteria for this honor are determined by the dean of the college. For 2002–2003, the requirement is a semester average of 3.4 or higher (without rounding); no failing, unsatisfactory, missing, or *incomplete* grades (even in physical education); and at least 12 letter-grade credits (not S-U). Students may earn Dean's List status retroactively if they meet these criteria after making up incomplete grades. Students who earn Dean's List status receive certificates from the Engineering Registrar's Office, and the honor is noted on the transcript.

Graduating with Distinction and Honors Program

Graduating with Distinction

Meritorious students graduating with a Bachelor of Science degree from the College of Engineering may also be designated *cum laude*, *magna cum laude*, or *summa cum laude*.

- Cum laude will be awarded to all engineering students with an overall GPA ≥ 3.5. Cum laude will also be awarded to all engineering students who received a semester GPA ≥ 3.5 in each of the last four semesters of attendance at Cornell; in each of these semesters, at least 12 letter graded credits must be taken with no failing, unsatisfactory, missing, or incomplete grades. If the student is an engineering co-op student, then the engineering co-op summer term will count as one of the last four. Students who were approved for pro-rated tuition in their final semester will be awarded cum laude if they received a semester GPA ≥ 3.5 in their last semester and meet the conditions above in the prior four semesters.
- Magna cum laude will be awarded to all engineering students with an overall GPA ≥ 3.75 (based on all credits taken at Cornell).
- Summa cum laude will be awarded to all engineering students with an overall GPA ≥ 4.0 (based on all credits taken at Cornell).

Note: All GPA calculations are minimums and are not rounded.

Field Honors Program

To be eligible for field honors, a student must enter a program with and maintain a cumulative GPA of ≥ 3.5. If the student's major field has an approved honors program and both the GPA and program requirements are fulfilled, the faculty of the field may recommend that a student graduate with the additional diploma and transcript notation of "With Honors." For more specific information, see the field program outline in this catalog.

S-U Grades

Many courses offered by the university may be taken either for a letter grade or for an S-U (satisfactory or unsatisfactory) grade designation. Under the S-U option, students earning the letter grade equivalent of C- or better in a course will receive a grade of S; those earning less than C- receive a grade of U. (Any course in which a U grade is received does not count toward graduation requirements.)

Engineering students may choose to receive an S-U grade option under the following conditions:

- The course in question must be offered with an S-U option.
- The student must have previously completed at least one full semester of study at Cornell.
- The proposed S-U course must count as either a liberal studies distribution or an approved elective in the engineering curriculum.
- Students may only elect to enroll S-U in one course each semester in which the choice between letter grade and S-U is an option. (Additional courses offered "S-U only" may be taken in the same semester as the "elected S-U" course.)

The choice of grading option for any course is initially made during the pre-enrollment period. Grading options may be changed, however, by submitting a properly completed Add/Drop Form to the Engineering Registrar by the end of the third week of classes. After this deadline, the grading option may not be changed, nor will a student be permitted to add a course in which they were previously enrolled (in the current semester) under a different grade option.

Residence Requirements

Candidates for an undergraduate degree in engineering must spend at least four semesters or an equivalent period of instruction as full-time students at Cornell. They must also spend at least three semesters of this time affiliated with an engineering field program or with the College Program.

Students who are on a voluntary leave of absence are permitted to register for courses extramurally only with the approval of their field (or the college, for unaffiliated students). No more than 18 credits earned through extramural study or acquired as transfer credit (or a combination thereof) after matriculation may be used to satisfy the requirements for the bachelor's degree in engineering.

Degree candidates may spend periods of time studying away from the Cornell campus with appropriate authorization. Information on programs sponsored by other universities and on procedures for direct enrollment in foreign universities is available at the Cornell Abroad Office, 474 Uris Hall. Programs should be planned in consultation with the staff of Engineering Advising, who can provide information on credit-evaluation policies and assist in the petitioning process.

Transferring within Cornell

It is not uncommon for students to change their academic or career goals after matriculation in one college and decide that their needs would be better met in another college at Cornell. While transfer between colleges is not guaranteed, efforts are made to assist students in this situation.

The office responsible for assisting students with the transfer process is the Internal Transfer Division Office. Students who wish to transfer out of the College of Engineering to another college at Cornell should consult initially with Engineering Advising.

Students who wish to transfer into the College of Engineering can apply at Engineering Advising—application forms are available in 167 Olin Hall. Students who would enter the college as second-semester sophomores or later must be accepted by a field program as part of the admission process. Students who would enter as a second-semester freshman or first-semester sophomore may be accepted into the college without the requirement of field affiliation but must be sponsored by a field program.

Students who hope to transfer into engineering should take courses in mathematics, chemistry, computer science, physics, and engineering that conform to the requirements of the Common Curriculum. Interested students should discuss their eligibility with an adviser in Engineering Advising, 167 Olin Hall.

Leave of Absence

A leave of absence may be voluntary, medical, or required. A description of each follows:

Voluntary Leave: Students sometimes find it necessary to suspend their studies. To do this, students must petition for a leave of absence for a specified period of time and receive written approval.

Affiliated students request leave through their fields. Unaffiliated students request leave through Engineering Advising; the first step is an interview to establish conditions for the leave and subsequent return. Those who take a leave before affiliating with a field and while not in good standing may be given a "conditional leave." This requires them to meet specific conditions, established at the time the leave is granted, before they will be reinstated.

Leaves of absence are not generally granted for more than two years. A leave of absence granted during a semester goes into effect on the day it is requested and lasts for a *minimum of six months*. If a leave is requested after the twelfth week of a semester, the courses in which the student was registered at the time of the request are treated as having been dropped (i.e., a "W" will appear on the transcript for each course). Students who owe money to the university are ineligible for leaves of absence. If courses taken during a leave are to satisfy Cornell degree requirements, they must be approved *in advance* through a formal transfer petition. (See previous section, "Transfer Credit," for details.)

Students who intend to take a leave of absence should check with the Office of Financial Aid and Student Employment to discuss financial implications; this is especially true for those who have taken out educational loans. Medical insurance eligibility may also be affected.

To return after a leave of absence, the conditions established when the leave was granted must be satisfied, and the college must be notified in writing at least six weeks before the beginning of the semester the in which student plans to return.

Medical Leave: Medical leaves are granted by the college only upon recommendation by a physician from Gannett Health Center. Such leaves are granted for at least six months and up to five years with the understanding that the student may return at the beginning of any term after the medical condition in question has been corrected. Students must satisfy the Gannett Health Center that the condition has been corrected before they may return. The student's academic standing will also be subject to review both at the time the leave is granted and upon the student's return.

Required Leave: A required leave of absence is imposed in cases where the academic progress of a student is so poor that continuing into the next semester does not appear prudent. An example where a leave of absence would be required might be failure in several courses in a semester. Unless the student is ahead in the curriculum, returning later to repeat the semester makes better academic sense than continuing without the necessary background. In many cases, the leave is dictated by courses that are only offered in the fall or the spring semester. Leaves are given when the probability of success is increased substantially by deferring the student's return by one semester (or, in unusual circumstances, one year).

Rejoining the College

Students wishing to rejoin the college who have not yet affiliated with a field should request permission to rejoin in a letter to Engineering Advising; affiliated students should contact their field office. This must be done at least six weeks before the beginning of the semester in which the student wishes to return. The letter should describe the student's activities while away from Cornell, detail any academic work completed during this time, and specify the courses the student intends to take upon return.

Withdrawal from the College

A withdrawal from the College of Engineering may be voluntary or required. Following is a description of each:

Voluntary Withdrawal: Students who voluntarily withdraw from the engineering degree program sever all connection with the college. Unaffiliated students who wish to withdraw should do so through Engineering Advising. Affiliated students should contact their field office. If a withdrawal is requested during the semester, courses in which the student is enrolled must be dropped in accordance with applicable regulations.

Any student who fails to register in the first three weeks of the semester, without benefit of a leave of absence or permission for study in absentia, will be deemed to have withdrawn.

Students who withdraw from the College of Engineering are eligible to apply for admission to one of the other six colleges at Cornell. The intra-university transfer process should be followed.

If students who have withdrawn subsequently wish to return, they must make a formal application for readmission. This is rarely granted. It is subject to a review of the student's academic background and depends on available space in the college and in the student's major field.

Required Withdrawal: Students are required to withdraw from the college only when their overall record indicates that they are either incapable of completing the program or not sufficiently motivated to do so. This action only withdraws them from the College of Engineering and does not, in and of itself, adversely affect their ability to transfer and complete a degree in one of the other colleges in the university.

ENGINEERING COOPERATIVE EDUCATION AND CAREER SERVICES

This office assists engineering students (freshmen through Ph.D.) in career development and job search issues, and administers the Engineering Cooperative Education Program (see separate entry under the Engineering Special Programs section). Individual advising and group seminars are available, and more than 300 national employers typically visit the office annually to recruit technical students and graduates; additional job opportunities are posted electronically. Both undergraduate and graduate students can use these services to pursue permanent or summer employment opportunities; however, students seeking co-op opportunities must meet specific requirements. Further information on all services is available from the Engineering Cooperative Education and Career Services Office, 201 Carpenter Hall (255-5006), and on the web at www.career.cornell.edu and www.engr.cornell.edu/coop.

BIOLOGICAL AND ENVIRONMENTAL ENGINEERING

M. F. Walter, chair; B. A. Ahner, L. D. Albright, D. J. Aneshansley, A. J. Baeumner, J. A. Bartsch, J. R. Cooke, A. K. Datta, K. G. Gebremedhin, D. A. Haith, J. B. Hunter, L. H. Irwin, W. J. Jewell, D. Luo, C. D. Montemagno, J.-Y. Parlange, N. R. Scott, R. M. Spanswick, T. S. Steenhuis, M. B. Timmons, L. P. Walker

Bachelor of Science Curriculum

Biological and Environmental Engineering (BEE) addresses three great challenges facing humanity today: ensuring an adequate and safe food supply in an era of expanding world population; protecting and remediating the world's natural resources, including water, soil, air, biodiversity and energy; and developing engineering systems that monitor, replace, or intervene in the mechanisms of living organisms. The undergraduate engineering program in the Department of Biological and Environmental Engineering has a unique focus on biological systems, including the environment, that is realized through a combination of fundamental engineering sciences, biology, engineering applications and design courses, and liberal studies. The program leads to a Bachelor of

Science degree and is accredited by the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET).

Two concentrations in Biological and Environmental Engineering are offered: biological engineering and environmental engineering. Students take courses in mathematics, statistics, computing, physics, chemistry, basic and advanced biology, fundamental engineering sciences (mechanics, thermodynamics, fluid mechanics, and transport processes), engineering applications, and design. Students select upper-level courses in the department in areas that include bioprocessing, soil and water management, biotechnology applications, bioinstrumentation, engineering aspects of animal physiology, environmental systems analysis, and waste treatment and disposal. Students strengthen their programs by selecting additional courses in the College of Engineering. They may complete minors of a second engineering major. Students planning for medical school also take additional lab-based courses in biology, biochemistry and organic chemistry. Throughout the curriculum, emphasis is placed on communications and teamwork skills and all students complete a capstone design project. Many undergraduate students participate in honors programs, undergraduate teaching and research, independent study, assistantships, research assistantships, design teams, Engineering Coop, and study abroad. Students completing the BEE major should have a strong aptitude for the sciences and mathematics and an interest in the complex social issues that surround technology.

Career opportunities cover the spectrum of private industry, public agencies, educational institutions, and graduate and professional programs in engineering, science, medicine, law, and other fields. In recent years, graduates have developed careers in environmental consulting, biotechnology, the pharmaceutical industry, biomedical engineering, management consulting, and international development.

The living world is all around us, and within us. The biological revolution continues and it has given rise to a growing demand for engineers and technical people who have studied biology and the environment, who have strong math and science skills, who can communicate effectively, and who are sensitive to the needs of people and who are interested in the challenges facing society. The Department of Biological and Environmental Engineering is educating the next generation of engineers to meet these challenges.

The department of Biological and Environmental Engineering is located in Riley-Robb Hall and operates specialized facilities that are among the largest and most complete of their kind in the world. For further details see the department's undergraduate programs publication, available at the BEE Student Service Office, 207 Riley-Robb Hall, or contact the field's advising coordinator, Professor Jim Bartsch, at 255–2800.

The field program requirements for those students joining the program in 2002–2003 are outlined.

Basic Subjects	*Credits*
MATH 191 (or 190), 192, 293, 294 Calculus for Engineers and Engineering Mathematics	16
Physics I and II (112 and 213)*	8
General Chemistry (207 or 211 or 215)*	4
Organic Chemistry*(257 or 357)*	3
BEE 151, Introduction to Computing	4
Biological Sciences*	12
Introductory	6–8
Advanced	6–4
Engineering Field Courses	
BEE 200, The BEE Experience	1
ENGRD 202, Mechanics of Solids	3
BEE 250, ENGR Applications	3
BEE 350, Bio & Environ Transport Proc	3
ENGRD 221, Thermodynamics	3
Statistics and Probability (ENGRD 270 or CEE 304)	3
Fluid Mechanics (CEE 331 or M&AE 323 or CHEME 323)	3–4
Upper-Level BEE courses (3 courses numbered 450–490; at least one of these must be an approved capstone design course)	9
Technical Engineering Electives (200 level or above; at least one of these must be an approved laboratory experience course)	17–18
Liberal Studies (two freshmen seminars and at least two courses in humanities or history)	24
Approved Electives	6
Total (minimum)	123

*Basic accredited curriculum. Specializations (options or pre-professional study) may be accommodated by selection of alternative or additional courses in the indicated area(s). For further information, please contact the BEE Student Services Office, 207 Riley Robb Hall or contact the field's advising coordinator, Professor Jim Bartsch at jab35@cornell.edu.

Biological and Environmental Engineering Honors Program

Eligibility

The Bachelor of Science degree with honors will be granted to engineering students who, in addition to having completed the requirements for a bachelor's degree, have satisfactorily completed the honors program in the Department of Biological and Environmental Engineering and have been recommended for the degree by the honors committee of the department. An honor's program student must enter with and maintain a cumulative GPA ≥ 3.5.

Content

An BEE honors program shall consist of at least nine credits beyond the 123 credit minimum required for graduation in BEE. These nine credits shall be drawn from one or more of the following with at least four credit hours in the first category:

- A significant research experience or honors project under the direct supervision of an BEE faculty member using BEE 499, Undergraduate Research. A written senior honors thesis must be submitted as part of this component.
- A significant teaching experience under the direct supervision of a faculty member or as part of a regularly recognized course in the department (e.g., BEE 151 or 250) under BEE 498, Undergraduate Teaching.
- Advanced or graduate courses. These additional courses must be technical in nature, i.e., in engineering, mathematics, biology, chemistry and physics at the 400+ and graduate level.

Note: no research, independent study, or teaching for which the student is paid may be counted toward the honors program.

Timing

All interested students must complete a written application no later than the end of the third week of the first semester of their senior year, but are encouraged to make arrangements with a faculty member during the second semester of their junior year. A student must be in the program for at least two semesters before graduation.

Procedures

Applications are available in the BEE Student Services office, 207 Riley Robb.

Each applicant to the BEE honors program must have an BEE faculty adviser to supervise the honors program. Written approval of the faculty member who will direct the research is required.

Option in Environmental Engineering

The Environmental Engineering Option provides BEE students the opportunity to follow a structured environmental engineering curriculum. The curriculum was developed and approved jointly by the faculty of BEE and Civil and Environmental Engineering (CEE). The Environmental Engineering Option in BEE and CEE share a common core of courses.

Students complete a prescribed program of courses within the framework of the BEE curriculum.

Chemistry/microbiology: Students must take at least two semesters of chemistry (CHEM 211/257 or CHEM 207/208). They must also satisfy the BEE organic chemistry requirement: either by taking organic chemistry as one of the two required chemistry courses (i.e., CHEM 257) or by taking CEE 451. The microbiology requirement of the Environmental Engineering option can also be met by taking CEE 451.

Chemistry: CHEM 211/257 or CHEM 207/208

Organic chemistry: CHEM 257 or CEE 451

Microbiology: CEE 451 or BIOMI 290

Fluid Mechanics: CEE 331

Probability and Statistics: CEE 304

Environmental Engineering: CEE 351

Environmental Quality Engineering: CEE 453

Laboratory Experience in Environmental Engineering: BEE 473 or 475: Watershed Engineering or Environmental Systems Analysis

Inquiries regarding this option should be addressed to the student's adviser or to Jim Bartsch, Undergraduate Advising Coordinator at jab35@cornell.edu.

Minor in Biological Engineering

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the Biological Engineering minor: A&EP, CEE, CHEME, COM S, EAS, ECE, M&AE, MS&E, and OR&IE. (Students may participate in either the Bioengineering Option **or** the Biological Engineering minor, but not both.)

Note: Students should meet with the BEE Program Coordinator as soon as they decide to pursue the minor. Then they will receive an BEE faculty adviser, who will assist them in completing the minor program.

Biological Engineering is the application of engineering to living systems. Examples of engineering efforts in this field include the development of new biosensor technologies, study and control of biologically based matter transformation systems, and development of engineered devices to study and regulate fundamental biological processes. The Biological Engineering minor is an opportunity for students to further their understanding of living systems and to increase their knowledge of the basic transport processes that occur within these systems. Courses in the minor provide opportunities to analyze and manipulate living systems at the molecular, cellular and system levels.

Requirements

To complete the minor, the student must take at least six (6) courses (minimum of 18 credits), which meet the following requirements:

Required course: BEE 350, Biological & Environmental Transport Processes

I. Analysis: Require two (2) from the following courses:

MS&E 304 (3)	Kinetics, Diffusion, and Phase Transformations
CHEME 313 (3)	Chemical Engineering Thermodynamics
CHEME 390 (3)	Reaction Kinetics and Reactor Design
CEE 437 (3)	Experimental Methods in Fluid Dynamics
BEE 685 (4)	Biological Engineering Analysis

II. Application: Require two (2) from the following courses:

BEE 450 (4)	Bioinstumentation
BEE 453 (3)	Computer-Aided Engineering Applications to Biomedical and Food Processes
BEE 454 (3)	Physiological Engineering
BEE 458 (3)	Biotechnology: Principles and Application
BEE 655 (3)	Thermodynamics and Its Applications
BEE 658 (3)	Biosensors and Bioanalytical Techniques
CHEME 643 (3)	Introduction to Bioprocess Engineering

III. Basic Sciences: One (1) from the following courses:

BIOBM 233 (3)	Introduction to Biomolecular Structure
BIOMI 290 (3)	General Microbiology
BIOBM 330–333 (2–4)	Principles of Biochemistry
BIOBM 434 (3)	Applications of Molecular Biology
BIONB 470 (3)	Biophysical Methods

Academic Standards: A letter grade of C- or better for each course in the minor.

Minor in Environmental Engineering

(Offered in cooperation with the School of Civil and Environmental Engineering)

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the environmental engineering minor: A&EP, CHEME, COM S, EAS, ECE, M&AE, MS&E, OR&IE. A fundamental challenge for the engineering profession is development of a sustainable society and environmentally responsible industry and agriculture reflecting an integration of economic and environmental objectives. We are called upon to be trustees and managers of our nation's resources, the air in our cities, and use and quality of water in our aquifers, streams, estuaries, and coastal areas. This minor encourages engineering students to learn about the scientific, engineering, and economic foundations of environmental engineering so that they are better able to address environmental management issues. The requirements for the environmental engineering minor are outlined below. For further details consult the Biological and Environmental Engineering Undergraduate Programs Office, 207 Riley-Robb Hall, or the Civil and Environmental Engineering Undergraduate Programs Office, 221 Hollister Hall.

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits), chosen as follows.

Students must select courses from the following group listings, with at least one course from each group.

Group A. Environmental Engineering Processes:

CEE 351	Environmental Quality Engineering
CEE 352	Water Supply Engineering
CEE 451	Microbiology for Environmental Engineering
CEE 453	Laboratory Research in Environmental Engineering
BEE 476	Solid Waste Engineering
BEE 478	Ecological Engineering
CEE 644	Environmental Applications of Geotechnical Engineering
BEE 651	Bioremediation
CEE 653	Water Chemistry for Environmental Engineering
CEE 655	Pollutant Transport and Transformation in the Environment
CEE 658	Sludge Treatment, Utilization, and Disposal
CEE 654	Aquatic Chemistry

Group B. Environmental Systems:

ENGRI 113*	Introduction to Environmental Systems (*May count only if taken before the student's junior year.)
BEE 475	Environmental Systems Analysis
CEE 529	Water and Environmental Resources Problems and Policies
CEE 597	Risk Analysis and Management
CEE 623	Environmental Quality Systems Engineering
BEE 678	Nonpoint Source Models

Group C. Hydraulics, Hydrology, and Environmental Fluid Mechanics:

CEE 331	Fluid Mechanics (CHEME 323 or M&AE 323 may be substituted for CEE 331)
CEE 332	Hydraulic Engineering
BEE 371	Hydrology and the Environment
CEE 431/ BEE 471	Geohydrology
CEE 432	Hydrology
CEE 435	Coastal Engineering
CEE 437	Experimental Methods in Fluid Dynamics
BEE 473	Watershed Engineering
BEE 474	Drainage and Irrigation Systems
CEE 633	Flow in Porous Media and Groundwater
CEE 655	Pollutant Transport and Transformation in the Environment
BEE 671	Analysis of the Flow of Water and Chemicals in Soils
BEE 672	Drainage

Academic Standards: A letter grade of C- or better in each course in the minor and a cumulative GPA of 2.0 or better for all courses in the minor.

Master of Engineering (Agricultural and Biological) Degree Program

The program for the M.Eng. (Agricultural and Biological) degree is intended primarily for those students who plan to enter engineering practice. The curriculum is planned as an extension of an undergraduate program in biological and environmental engineering but can accommodate graduates of other engineering disciplines. The curriculum consists of 30 credits of courses intended to strengthen the students' fundamental knowledge of engineering and develop their design skills. At least three to nine of the required 30 credits are earned for an engineering design project that culminates in a written and oral report.

The program is designed to be flexible so that the candidate may concentrate in any of a variety of specialty areas: biological engineering, energy, environmental engineering, environmental management, food processing engineering, international agriculture, local roads, machine systems, soil and water engineering, and structures and environment. Elective courses are chosen from among engineering subject areas relevant to the student's interests and design project. Courses in technical communication, mathematics, biology, and the physical sciences may also be taken as part of a coherent program. Master of Engineering students in Biological and Environmental Engineering can qualify for the Dean's Certificate in energy, manufacturing, or bioengineering by choosing their design project and a number of electives from the designated topic areas. More information is available from the BEE Student Services Office, 207 Riley Robb Hall (255–2173), or by e-mail at BEEgradfield@cornell.edu.

APPLIED AND ENGINEERING PHYSICS

J. D. Brock, director; B. R. Kusse, associate director for undergraduate studies; A. L. Gaeta, director of graduate studies, T. A. Cool, H. G. Craighead, M. S. Isaacson, V. O. Kostroun, M. Lindau, R. V. E. Lovelace, L. Pollack, J. Silcox, W. W. Webb; F. W. Wise adjunct faculty: D. H. Bilderback; senior research associate: E. J. Kirkland

Bachelor of Science Curriculum

The undergraduate engineering physics curriculum is designed for students who want to pursue careers of research or development in applied science or advanced technology and engineering. Its distinguishing feature is a focus on the physics and mathematics fundamentals, both experimental and theoretical, that are at the base of modern engineering and research and have a broad applicability in these areas. By choosing areas of concentration, the students may combine this physics base with a good background in a conventional area of engineering or applied science.

The industrial demand for engineering physics graduates with baccalaureates is high, and many students go directly to industrial positions where they work in a variety of areas that either combine, or are in the realm of, various more conventional areas of engineering. Recent examples include bioengineering, computer technology, electronic-circuit and instrumentation design, energy conversion, environmental engineering, geological analysis, laser and optical technology, microwave technology, nuclear technology, software engineering, solid-state-device development, technical management, and financial consulting. A number of our graduates go on for advanced study in all areas of basic and applied physics, as well as in a diverse range of areas in advanced science and engineering. Examples include applied physics, astrophysics, atmospheric sciences, biophysics, cell biology, computer science and engineering, electrical engineering, environmental science, fluid mechanics, geotechnology, laser optics, materials science and engineering, mechanical engineering, medical physics, mathematics, medicine, nuclear engineering, oceanography, and physics. The undergraduate program can also serve as an excellent preparation for medical school, business school, or specialization in patent law.

The Engineering Physics program fosters this breadth of opportunity because it both stresses the fundamentals of science and engineering and gives the student direct exposure to the application of these fundamentals. Laboratory experimentation is emphasized, and ample opportunity for innovative design is provided. Examples are ENGRI 110, The Laser and Its Applications in Science, Technology, and Medicine (a freshman Introduction to Engineering course); ENGRD/A&EP 264, Computer-Instrumentation Design (a recommended sophomore engineering distribution course); A&EP 330, Modern Experimental Optics (a junior/senior course); A&EP 363, Electronic Circuits (a sophomore/junior course); PHYS 410, Advanced Experimental Physics; and A&EP 438, Computational Engineering Physics (a senior computer laboratory).

Undergraduates who plan to enter the field program in Engineering Physics are advised to arrange their Common Curriculum with their developing career goals in mind. Students are also encouraged to take PHYS 112 or PHYS 116 during their first semester (if their advanced placement credits permit) and are recommended to satisfy the computing applications or technical writing requirement with the engineering distribution course ENGRD 264. Engineering physics students need to take only two engineering distribution courses, since A&EP 333, which they take in their junior year, counts as a third member of this category. Engineering Physics students are advised to take A&EP 363 in the spring semester of the sophomore year. Students with one semester of advanced placement in math, who have received a grade of A- or better in MATH 192, may wish to explore accelerating their mathematics requirements so as to enroll in A&EP 321 and 322 in the sophomore year. For advice on this option, consult with the A&EP associate director.

In addition to the requirements of the Engineering Common Curriculum,* the upperclass course requirements of the field program are as follows:

Course	*Credits*
A&EP 333, Mechanics of Particles and Solid Bodies	4
A&EP 355, Intermediate Electromagnetism	4
A&EP 356, Intermediate Electrodynamics	4
A&EP 361, Introductory Quantum Mechanics	4
A&EP 363, Electronic Circuits	4
A&EP 423, Statistical Thermodynamics	4
A&EP 434, Continuum Physics	4
PHYS 410, Advanced Experimental Physics	4
A&EP 321, Mathematical Physics I; or MATH 421 (applied mathematics)	4
A&EP 322, Mathematical Physics II; or MATH 422 (applied mathematics)	4

Six field-approved electives (18–23 credits), of which five must be technical. The technical electives are expected to be upper-level courses (300 or above).

Total field credits=58 credit hours minimum.

*The Engineering Common Curriculum allows students to take only four courses each semester of their freshman year if they so desire. This course load is fully consistent with the requirements of the EP major, but entering students with strong preparation are encouraged to consider taking an additional course during one or both semesters of the freshman year so that they may have additional flexibility in developing a strong, individualized educational program in their latter years, and for allowing options such as a semester or year abroad or early graduation.

Two of the four credits of PHYS 410 required for the BS degree in Engineering Physics can be satisfied by successfully completing A&EP/PHYS 330. The remaining two credits of PHYS 410 can then be satisfied by taking PHYS 400 for two credits, provided that the experiments completed in PHYS 400 do not overlap with those in A&EP/PHYS 330. (A list of experiments that are not appropriate will be prepared by A&EP faculty and made available in the A&EP office.) If a student chooses this option, A&EP/PHYS 330 may also count as a technical elective, provided the remaining three technical electives are four credits each.

‡If a scientific computing course was not selected as an engineering distribution course, one of these technical electives may be needed to satisfy the computing applications requirement. For students going on to graduate school a third course in mathematics is recommended.

Choosing elective courses. A distinctive aspect of the Engineering Physics curriculum is the strong opportunity it provides students to develop individualized programs of study to meet their particular educational and career goals. These can include the pursuit of a dual major or the development of a broad expertise in one or more of a number of advanced technical and scientific areas. With at least seven technical and approved electives in the sophomore, junior, and senior years, Engineering Physics majors are encouraged to work closely with their adviser to develop a coherent academic program that is in accordance with those goals. For those students who look toward an industrial position after graduation, these electives should be chosen to widen their background in a specific area of practical engineering. A different set of electives can be selected as preparation for medical, law, or business school. For students who plan on graduate studies, the electives provide an excellent opportunity to explore upper-level and graduate courses, and to prepare themselves particularly well for graduate study in any one of a number of fields. Various programs are described in a special brochure available from the School of Applied and Engineering Physics, Clark Hall. Students interested in these options are advised to consult with their EP adviser, a professor active in their area of interest, or with the associate director of the school, Professor Bruce Kusse.

Electives need not be all formal course work: qualified students are encouraged to undertake independent study under the direction of a member of the faculty (A&EP 490). This may include research or design projects in areas in which faculty members are active.

The variety of course offerings and many electives provide flexibility in scheduling. If scheduling conflicts arise, the school may allow substitution of courses nearly equivalent to the listed required courses.

The Engineering Physics Program requires that a minimum of a (B-) or better be attained in each physics and mathematics courses taken by a student before entering the Engineering Physics field unless approval is obtained from the A&EP associate director. To remain in good standing in the field, the engineering physics student is expected to pass every course for which he or she is registered, to earn a grade of C- or better in specifically required courses, and to attain each semester a grade-point average for that semester of at least 2.3.

Engineering Physics Honors Program

Eligibility

The Bachelor of Science degree with honors will be conferred upon those students who, while completing the requirements for a bachelor degree, have satisfactorily completed the honors program in the Department of Engineering Physics and have been recommended for the degree by the honors committee of the department. An honors program student must enter with and maintain a cumulative GPA≥ 3.5.

Content

The student must

1. Complete at least eight credits of field approved electives at the 400-level or higher and receive a minimum grade of an A- in each of the courses taken to fulfill this eight-credit requirement. These eight credits are in addition to the credits obtained by completing the senior thesis or special project requirement as discussed in item 2.
2. Enroll in A&EP 490 or an equivalent course over two semesters for the purpose of completing an independent research project or senior thesis under the supervision of a Cornell engineering or science faculty member. The minimum enrollment is to be two credits in the first semester and four credits in the second. The level of work required for a successful completion of this project or thesis is to be consistent with the amount of academic credit granted.

Timing

All interested students must complete a written application no later than the end of the third week of the first semester of their senior year, but are encouraged to make arrangements with a faculty member during the second semester of their junior year. A student must be in the program for at least two semesters before graduation.

Procedures

Before enrolling in A&EP 490, or the equivalent, the honors candidate must submit a brief proposal outlining the topic and scope of the proposed project or thesis and a faculty supervisor's written concurrence to the associate director for undergraduate studies. This proposal will be reviewed by the A&EP Honors Committee and either approved or returned to the candidate to correct deficiencies in the proposal. The proposed research project or senior thesis is to consist of a research, development, or design project and must go beyond a literature search. The final steps in completing the honors project are a written and oral report. The written report is to be in the form of a technical paper with, for example, an abstract, introduction, methods section, results section, conclusions section, references, and figures. This report will be evaluated by the faculty supervisor and the chair of the A&EP Honors Committee. Following the completion of the written report, an oral report is to be presented to an audience consisting of the faculty supervisor, the chair of the Honors Committee, and at least one other departmental faculty member, along with the other honors candidates. The final research project course grade will be assigned by the faculty supervisor, following the oral presentation and after consultation with the chair of the Honors Committee. A minimum grade of A- is necessary for successful completion of the honors requirement.

Master of Engineering (Engineering Physics) Degree Program

The M.Eng. (Engineering Physics) degree may lead directly to employment in engineering design and development or may be a basis for further graduate work. Students have the opportunity to broaden and deepen their preparation in the general field of applied physics, or they may choose the more specific option of preparing for professional engineering work in a particular area such as laser and optical technology, nanostructure science and technology, device physics, materials characterization, or software engineering. A wide latitude is allowed in the choice of the required design project.

One example of a specific area of study is solid-state physics and chemistry as applied to nano-structure science and technology. Core courses in this specialty include the micro-characterization of materials (A&EP 661) and the microprocessing and microfabrication of materials (A&EP 662). The design project may focus on such areas as semiconductor materials, device physics, nanostructure technology, or optoelectronics. Another area of study may be applied optics where core courses can be chosen from applied physics, electrical engineering, and physics.

Each individual program is planned by the student in consultation with the program chair. The objective is to provide a combination of a good general background in physics and introductory study in a specific field of applied physics. Candidates may enter with an undergraduate preparation in physics, engineering physics, or engineering. Those who have majored in physics usually seek advanced work with an emphasis on engineering; those who have majored in an engineering discipline generally seek to strengthen their physics base. Candidates coming from industry usually want instruction in both areas. All students granted the degree will have demonstrated competence in an appropriate core of basic physics; if this has not been accomplished at the undergraduate level, subjects such as electricity and magnetism, or classical, quantum, and statistical mechanics should be included in the program.

The general requirement for the degree is a total of 30 credits for graduate-level courses or their equivalent, earned with a grade of C or better and distributed as follows:

1) a design project in applied science or engineering with a written final report (not less than 6 nor more than 12 credits)
2) an integrated program of graduate-level courses, as discussed below (17 to 23 credits)
3) a required special-topics seminar course (one credit)

The design project, which is proposed by the student and approved by the program chair, is carried out on an individual basis under the guidance of a member of the university faculty. It may be experimental or theoretical in nature; if it is not experimental, a laboratory physics course is required.

The individual program of study consists of a compatible sequence of courses focused on a specific area of applied physics or engineering. It's purpose is to provide an appropriate combination of physics and physics-related courses (applied mathematics, statistical mechanics, applied quantum mechanics) and engineering electives (such as courses in biophysics, chemical engineering, electrical engineering, materials science, computer science, mechanical engineering, or nuclear engineering). Additional science and engineering electives may be included. Some courses at the senior level are acceptable for credit toward the degree; other undergraduate courses may be required as prerequisites but are not credited toward the degree.

Students interested in the M.Eng. (Engineering Physics) degree program should contact Professor Bruce Kusse.

APPLIED MATHEMATICS

The Center for Applied Mathematics administers a broadly based interdepartmental graduate program that provides opportunities for study and research in a wide range of the mathematical sciences. For detailed information on opportunities for graduate study in applied mathematics, contact the director of the Center for Applied Mathematics, 657 Frank H. T. Rhodes Hall.

There is no special undergraduate degree program in applied mathematics. Undergraduate students interested in application-oriented mathematics may select an appropriate program in the Department of Mathematics or one of the departments in the College of Engineering.

A list of selected graduate courses in applied mathematics may be found in the description of the Center for Applied Mathematics, in the section "Interdisciplinary Centers and Programs."

CHEMICAL AND BIOMOLECULAR ENGINEERING

M. L. Shuler, director; K. E. Ackley, A. B. Anton, L. A. Archer, A. M. Center, P. Clancy, C. Cohen, T. M. Duncan, J. R. Engstrom, F. A. Escobedo, Y. L. Joo, D. L. Koch, K. H. Lee, W. L. Olbricht, D. Putnam, P. H. Steen

Bachelor of Science Curriculum

The undergraduate field program in Chemical and Biomolecular Engineering comprises a coordinated sequence of courses beginning in the sophomore year and extending through the fourth year. Special programs in biochemical engineering and polymeric materials are available. Students who plan to enter the field program take CHEM 208 during the freshman year. The program for the last three years, for students who have taken an Introduction to Engineering course during the first year is as follows:

Semester 3	*Credits*
MATH 293, Engineering Mathematics	4
PHYS 213, Electricity and Magnetism	4
CHEM 389, Physical Chemistry I (engineering distribution)	4
ENGRD 219, Mass and Energy Balances (engineering distribution)	3
Humanities or social sciences	3
Semester 4	
MATH 294, Engineering Mathematics	4
CHEM 323, Fluid Mechanics	3
CHEM 290–391, Physical Chemistry (field)	6
ENGRD 241	3
Humanities or social sciences	3
Semester 5	
CHEM 357, Introductory Organic Chemistry	3
CHEM 251, Organic Chemistry Laboratory	2
CHEME 313, Chemical Engineering Thermodynamics	4
CHEME 324, Heat and Mass Transfer	3
Humanities or social sciences	3
Semester 6	
Advanced Science elective†	3
CHEME 301, Nonresident Lectures	1
CHEME 332, Analysis of Separation Processes	3
CHEME 372, Introduction to Process Dynamics and Control	1
CHEME 390, Reaction Kinetics and Reactor Design	3
Humanities or social sciences	3
Semester 7	
CHEME 432, Chemical Engineering Laboratory	4
Electives*	9
Humanities or Social Sciences	3
Semester 8	
CHEME 462, Chemical Process Design	4
Humanities or social sciences	3
Electives*	3
Approved elective	3

*The electives in semester seven and eight comprise six credits of field approved electives, and six credits of advanced CHEME electives. Advanced CHEME electives include any CHEME course 400+ level, except CHEME 490, 491, 492, 520, and 572.

†Advanced science electives include BIOMI 290, General Microbiology Lectures; BIOBM 330, 331, 332, and 333, Principles of Biochemistry; CEE 654, Aquatic Chemistry; CHEME 480, Chemical Processing of Electronic Materials; CHEME 481, Biomedical Engineering; CHEME 640, Polymeric Materials; CHEME 643, Introduction to Bioprocess Engineering; FOOD 417, Food Chemistry I; MS&E 206, Atomic and Molecular Structure of Matter; MS&E 305, Electronic Structure of Matter; MS&E 306, Electrical, Optical, and Magnetic Properties of Materials; MS&E 541, Microprocessing of Materials; MS&E 531, Introduction to Ceramics; MS&E 521, Properties of Solid Polymers; T&AM 310, Advanced Engineering Analysis I; any A&EP course numbered 333 or above; any CHEM course numbered 301 or above; any PHYS course numbered 300 or above.

Master of Engineering (Chemical) Degree Program

The professional master's degree, M.Eng. (Chemical), is awarded at the end of one year of graduate study with successful completion of 30 credits of required and elective courses in technical fields including engineering, mathematics, chemistry, physics, and business administration. Courses emphasize design and optimization based on the economic factors that affect design alternatives for processes, equipment, and plants. General admission and degree requirements are described in the college's introductory section.

Specific requirements include

1) two courses in advanced chemical engineering fundamentals chosen from CHEME 711, 713, 731, 732, and 751
2) two courses in applied chemical engineering science chosen from CHEME 480, 520, 564, 566, 640, 643, 656, and 661
3) a minimum of three credits of a design project, CHEME 565

Dean's certificate programs in Bioengineering, Engineering Management, Energy Engineering, and Manufacturing are available. A program offered jointly with the Food Science Department is also available, leading to both the Master of Engineering and the Master of Professional Studies degrees.

CIVIL AND ENVIRONMENTAL ENGINEERING

J. F. Abel, S. L. Billington, J. J. Bisogni, Jr., W. H. Brutsaert, P. G. Carr, E. A. Cowen, R. A. Davidson, R. I. Dick, L. B. Dworsky, K. Gebremedhin, J. M. Gossett, M. D. Grigoriu, D. A. Haith, K. C. Hover, A. R. Ingraffea, F. H. Kulhawy, L. W. Lion, P. L-F. Liu, D. P. Loucks, J. R. Mbwana, A. H. Meyburg, L. K. Nozick, P. Petrina, T. D. O'Rourke, K. D. Papoulia, T. Peköz, W. D. Philpot, R. E. Richardson, M. J. Sansalone, R. E. Schuler, C. A. Shoemaker, J. R. Stedinger, H. E. Stewart, M. A. Turnquist, F. Wayno, M. Weber-Shirk, R. N. White

Bachelor of Science Curriculum

The School of Civil and Environmental Engineering (CEE) offers an accredited undergraduate program in civil engineering and permits students to pursue one of two options leading to the B.S. degree: civil engineering or environmental engineering. Within civil engineering, while it is not necessary to do so, students may concentrate in structural engineering, geotechnical engineering, fluid mechanics and hydrology, water resource systems, or transportation. The environmental engineering curriculum emphasizes study of environmental engineering, water resource systems, and fluid mechanics and hydrology. Sample curricula are available in the CEE Undergraduate Program Office, 221 Hollister Hall.

Requirements for Admission to the Field:

Students planning to enter the field program in Civil and Environmental Engineering are required to complete the following courses before or during the first semester of the sophomore year with a grade of C– or better: for the civil option, ENGRD 202, Mechanics of Solids; for the environmental option, either ENGRD 202, Mechanics of Solids or CHEM 208, General Chemistry. In addition, the field requires a cumulative grade point average of at least 2.0 both overall and in engineering and sciences courses.

Recommended Engineering Distribution Courses:

Students in the environmental option are required to take ENGRD 202 (Mechanics of Solids), as an engineering distribution course. The second engineering distribution may be selected according to their interests, and the following engineering distribution courses are recommended: ENGRD 201 Introduction to the Physics and Chemistry of the Earth, ENGRD 219 Mass and Energy Balances, ENGRD 221 Thermodynamics, ENGRD 250 Engineering Applications in Biological Systems, BIO G 101 and 103 Biological Sciences Lecture and Laboratory, BIO G 105 Introduction to Biology, BIO G 107 General Biology, or CHEM 389 Physical Chemistry.

Recommended engineering distribution courses for students planning to enter the civil engineering option are:

ENGRD 261, Introduction to Mechanical Properties of Materials, for students interested in structural engineering or civil engineering materials;

ENGRD 201, Introduction to the Physics and Chemistry of the Earth, for students interested in geotechnical engineering;

ENGRD 221, Thermodynamics, for students interested in fluid mechanics and hydraulics/hydrology;

ENGRD 211, Computers and Programming, for students interested in transportation;

ENGRD 241, Engineering Computation,* for all students.

Field Program:

Civil Engineering Option

For the field program in Civil Engineering, students may elect to substitute CHEM 208 for PHYS 214. The following nine courses are required in addition to those required for the Common Curriculum.

Core Courses	*Credits*
ENGRD 203, Dynamics	3
ENGRD 241, Engineering Computation*	3
CEE 304, Uncertainty Analysis in Engineering†	4
CEE 323, Engineering Economics and Management	3
CEE 331, Fluid Mechanics	4
CEE 341, Introduction to Geotechnical Engineering and Analysis	4
CEE 351, Environmental Quality Engineering**	3
CEE 361, Introduction to Transportation Engineering**	3
CEE 371, Modeling of Structural Systems	4

Additional requirements include a set of two field-approved electives and three design electives from an approved list of courses that is available in the school office. In addition, students must complete one technical communications course from among the courses designated ENGRC or approved communications courses. If the technical communications course is taken as an expressive art, then students must take an additional approved elective from a department or school other than Civil and Environmental Engineering.

*ENGRD 241 can be used to satisfy both the computer application requirement and a field program requirement. If a student elects to use this course as a second distribution course, the student must take an additional field-approved elective to fulfill the core course requirements.

†ENGRD 270 may be accepted (by petition) as a substitute for CEE 304 in the field program, but only if ENGRD 270 is taken before entry into the field, or in some special cases where co-op or study abroad programs necessitate such a substitution.

Students may substitute any Field-Approved Elective for either CEE 351 or CEE 361, **if** they complete either CEE 376 or CEE 472 and also complete CEE 473. However, this substitute course then counts as a Core Course only and not as one of the required five CEE Design courses and Field Approved electives.

Environmental Engineering Option

These option requirements apply to all students in the Classes of 2002 and later. For the field program in Environmental Engineering, students must take CHEM 208 in place of PHYS 214. The following nine courses are required in addition to those required for the Common Curriculum:

Core Courses	*Credits*
Introductory Biology‡ (BIO G 101 & 103, BIO G 105, or BIO G 107	4
ENGRD 241, Engineering Computation*	3
CEE 304, Uncertainty Analysis in Engineering†	4
CEE 323, Engineering Economics and Management	3
CEE 331, Fluid Mechanics	4
CEE 341, Introduction to Geotechnical Engineering and Analysis	4
CEE 351, Environmental Quality Engineering	3
CEE 451, Microbiology for Environmental Engineering§	3
CEE 453, Laboratory Research in Environmental Engineering	3
BEE 475, Environmental Systems Analysis	3

Additional requirements include one‡ field-approved elective and three design electives from an approved list of courses that is available in the CEE Undergraduate Program office. In addition, students must complete one technical communications course from among the courses designated ENGRC or approved communications courses. If the technical communications course is taken as an expressive art, then students must take an additional approved elective.

‡The requirement for students prior to the class of 2002 is two field-approved electives and no requirement for a core course in introductory biology.

§Students planning graduate level study in environmental engineering may take BIOMI 290 Introduction to Microbiology in place of CEE 451. These students should also take CHEM 257 or CHEM 357 Introduction to Organic Chemistry as an approved elective.

Civil and Environmental Engineering Honors Program

Eligibility

The Bachelor of Science degree with honors will be granted to students who, in addition to having completed the requirements for a bachelor degree, have satisfactorily completed the honors program in Civil and Environmental Engineering and have been recommended for the degree by the faculty of the school. An honors program student must enter with and maintain a cumulative GPA≥ 3.5.

Content

A CEE honors program shall consist of at least nine credits beyond the minimum required for graduation in CEE. These nine credits shall be drawn from one or more of the following components:

1. A significant research experience or honors project under the direct supervision of a CEE faculty member using CEE 400: Senior Honors Thesis (1–6 credits per semester). A significant written report or senior honors thesis must be submitted as part of this component.
2. A significant teaching experience under the direct supervision of a faculty member or as part of a regularly recognized course in the College of Engineering (i.e., ENGRG 470: Peer Teaching in Engineering or CEE 401: Undergraduate Teaching in CEE (1–3 credits per/semester).
3. Advanced or graduate courses at the 500-level or above.

The minimum number of credits in any component included in a program should be two. No research, independent study, or teaching for which the student is paid may be counted toward the honors program.

Timing

All interested students must apply no later than the beginning of the first semester of their senior year, but are encouraged to apply as early as the first semester of their junior year. All honors program students must be in the program for at least two semesters prior to graduation.

Procedures

Each applicant to the CEE honors program must have a faculty adviser or faculty mentor to supervise the student's individual program. (This need not be the student's faculty adviser.) The application to the program shall be a letter from the student describing the specific proposed honors program and include the explicit approval of the faculty adviser and the honors adviser. Each program must be approved by the CEE Curriculum Committee, although the committee may delegate approval authority to the associate director for all but unusual proposals.

Engineering Minor Programs

The School of Civil and Environmental Engineering currently offers three engineering minor programs: civil infrastructure, engineering management, and environmental engineering (offered in cooperation with the Department of Biological and Environmental Engineering). Descriptions and requirements for each program follow:

Minor in Civil Infrastructure

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the civil infrastructure minor: BEE, A&EP, CHEME, COM S, EAS, ECE, M&AE, MS&E, OR&IE.

The minor in civil infrastructure is intended to introduce engineering undergraduates to the engineering methodologies of mechanics, materials, analysis, design, and construction and to show how these are used in solving problems in the development maintenance and operation of the built environment which is vital for any modern economy.

The requirements for the civil infrastructure minor are outlined below. For further details consult the Civil and Environmental Engineering Undergraduate Programs Office, 221 Hollister Hall.

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits), chosen as follows:

I. Required Course: ENGRD 202 Mechanics of Solids

II. Additional Courses: choose any 5 (groupings are for information only)*

Geotechnical Engineering

CEE 341 Introduction to Geotechnical Engineering and Analysis

CEE 640 Foundation Engineering

CEE 641 Retaining Structures and Slopes

CEE 644 Environmental Applications of Geotechnical Engineering

Structural Engineering

CEE 371 Modeling of Structural Systems

CEE 376 Physical and Computational Material Simulation

CEE 472 Fundamentals of Structural Mechanics

CEE 473 Design of Concrete Structures

CEE 474 Design of Steel Structures

CEE 481 LRFD-Based Engineering of Wood Structures

CEE 672 Fundamentals of Structural Mechanics

CEE 673 Advanced Structural Analysis

Other Related Courses

CEE 332 Hydraulic Engineering

CEE 361 Introduction to Transportation Engineering

CEE 595 Construction Planning and Operations

*Other CEE courses approved by petition in advance.

Academic Standards: A letter grade of C or better for each course in the minor.

Minor in Engineering Management

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the engineering management minor: BEE, A&EP, CHEME, COM S, EAS, ECE, M&AE, MS&E.

This minor focuses on giving engineering students a basic understanding of engineering economics, accounting, statistics, project management methods, and analysis tools necessary to manage technical operations and projects effectively. The minor provides an important set of collateral skills for students in any engineering discipline.

The requirements for the engineering management minor are outlined below. For further details, consult the Civil and Environmental Engineering Undergraduate Programs Offices, 221 Hollister Hall.

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits), chosen as follows:

I. Required Courses (3):

CEE 304† Uncertainty Analysis in Engineering

or ENGRD 270 Basic Engineering Probability and Statistics

or ECE 310 Introduction to Probability and Random Signals

CEE 323 Engineering Economics and Management

OR&IE 350 Financial and Managerial Accounting

II. Additional Courses—choose any 3*

CEE 490 Management Practice in Project Engineering

CEE 506 Civil and Environmental Systems

CEE 593 Engineering Management Methods I: Data, Information, and Modeling

CEE 594 Engineering Management Methods II: Managing Uncertain Systems

CEE 595 Construction Planning and Operations

CEE 597 Risk Analysis and Management

CEE 598 Introduction to Decision Analysis

NBA 401 Entrepreneurship for Scientists and Engineers

or MAE/ENGRG 461 Entrepreneurship for Engineers

or BEE 489 Engineering Entrepreneurship, Management and Ethics

*Other courses approved by petition in advance.

†T&AM 310 may not be substituted for CEE 304.

Academic Standards: a letter grade of C or better for each course in the minor.

Minor in Environmental Engineering

(Offered in cooperation with the Department of Biological and Environmental Engineering)

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the environmental engineering minor: A&EP, CHEME, COM S, EAS, ECE, M&AE, MS&E, OR&IE.

A fundamental challenge for the engineering profession is development of a sustainable society and environmentally responsible industry and agriculture reflecting an integration of economic and environmental objectives. We are called upon to be trustees and managers of our nation's resources, the air in our cities, and use and quality of water in our aquifers, streams, estuaries and coastal areas. This minor encourages engineering students to learn about the scientific, engineering, and economic foundations of environmental engineering so that they are better able to address environmental management issues.

The requirements for the environmental engineering minor are outlined below. For further details consult the Civil and Environmental Engineering Undergraduate Programs Office, 221 Hollister Hall, or the Biological and Environmental Engineering Undergraduate Programs Office, 207 Riley-Robb Hall.

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits), chosen as follows:

Students must select courses from the following group listings, with at least one course from each group.

Group A. Environmental Engineering Processes:

CEE 351 Environmental Quality Engineering

CEE 352 Water Supply Engineering

CEE 451 Microbiology for Environmental Engineering

CEE 453 Laboratory Research in Environmental Engineering

BEE 476 Solid Waste Engineering

BEE 478 Ecological Engineering

CEE 644 Environmental Applications of Geotechnical Engineering

BEE 651 Bioremediation

CEE 653 Water Chemistry for Environmental Engineering

CEE 655 Pollutant Transport and Transformation in the Environment

CEE 658 Sludge Treatment, Utilization and Disposal

CEE 654 Aquatic Chemistry

Group B. Environmental Systems:

ENGRI 113/CEE 113* Solving Environmental Problems for Urban Regions (*May count only if taken before the student's junior year.)

BEE 475 Environmental Systems Analysis

CEE 529 Water and Environmental Resources Problems and Policies

CEE 597 Risk Analysis and Management

CEE 623 Environmental Quality Systems Engineering

BEE 678 Nonpoint Source Models

Group C. Hydraulics, Hydrology, and Environmental Fluid Mechanics:

CEE 331 Fluid Mechanics (CHEME 323 or M&AE 323 may be substituted for CEE 331)

CEE 332 Hydraulic Engineering

BEE 371 Hydrology and the Environment

CEE 431/BEE 471 Geohydrology

CEE 432 Hydrology

CEE 435 Coastal Engineering

CEE 436 Case Studies in Environmental Fluid Mechanics

CEE 437 Experimental Methods in Fluid Dynamics

BEE 473 Watershed Engineering

BEE 474 Drainage and Irrigation Systems

CEE 631 Flow and Contaminant Transport Modeling in Groundwater

CEE 633 Flow in Porous Media and Groundwater

CEE 655 Transport, Mixing, and Transformation in the Environment

BEE 671 Analysis of the Flow of Water and Chemicals in Soils

BEE 672 Drainage

Academic Standards: A letter grade of C- or better in each course in the minor and a cumulative GPA of 2.0 or better for all courses in the minor.

Master of Engineering (Civil) Degree Program

The M.Eng. (Civil) degree program is a 30-credit (usually 10-course) curriculum designed to prepare students for professional practice. There are two options in this program: one in civil and environmental engineering design and one in engineering management. Both options require a broad-based background in an engineering field. Applicants holding an ABET-accredited (or equivalent) undergraduate degree in engineering automatically satisfy this requirement. Those without such preparation will require course work beyond the graduate program's 30-credit minimum to fulfill the engineering preparation requirement. Both options also require one course in professional (design-option) or managerial (management-option) practice and a two-course project sequence. The project entails synthesis, analysis, decision making, and application of engineering judgment. Normally it is undertaken in cooperation with an outside practitioner, with some options indicating an intensive, full-time session between semesters. The general degree requirements and admissions information are described above in the section entitled "Master of Engineering Degree Programs." Each student's program of study is designed individually in consultation with an academic adviser and then submitted to the school's Professional Degree Committee for approval.

For the M.Eng. (Civil) program in civil and environmental engineering design options, the requirements are:

1) Three courses, one in professional engineering practice (CEE 590) and a two-course design project (CEE 501 and 502).
2) Specialization in a major concentration area—three to five courses in either environmental engineering, environmental fluid mechanics/hydrology, geotechnical engineering, structural engineering, transportation management, or water resources and environmental systems engineering.
3) Technical electives.
4) Study in a related area or areas.

Courses taken as technical electives or in the related subject area(s) may consist of graduate or advanced courses in fields related to the major concentration area, either inside or outside of the school.

For the M.Eng. (Civil) program in the engineering management option, the requirements are:

1) Five courses: Project Management (CEE 590), Engineering Management Methods (CEE 593 and 594), and the Management Project (CEE 591 and 592).
2) One course in finance, accounting, or engineering economics, as appropriate given a student's background.
3) One course in individual and/or organizational behavior from a recommended list.
4) Three courses from a disciplinary or functional specialization, subject to adviser's approval.

The School of Civil and Environmental Engineering cooperates with the the Johnson Graduate School of Management in two joint programs leading to both Master of Engineering and Master of Business Administration degrees. See the introductory section under College of Engineering for details.

COMPUTER SCIENCE

C. Van Loan, chair; B. Arms, G. Bailey, K. Birman, C. Cardie, R. Caruana, T. Coleman, R. L. Constable, A. Demers, R. Elber, D. Fan, J. Gehrke, D. Greenberg, J. Halpern, J. E. Hopcroft, D. Huttenlocher, T. Joachims, J. Kleinberg, D. Kozen, L. Lee, J. Matthews, G. Morrisett, A. Myers, K. Pingali, R. Rugina, F. B. Schneider, D. Schwartz, B. Selman, P. Seshadri, J. Shanmugasundaram, D. Shmoys, E. G. Sirer, E. Tardos, R. Teitelbaum, S. Vavasis, T. vonEicken, G. Yona, R. Zabih

Bachelor of Science Curriculum

The Department of Computer Science is affiliated with both the College of Arts and Sciences and the College of Engineering. Students in either college may major in computer science.

For the most current and accurate details, visit our web site at www.cs.cornell.edu/ugrad

The Major

Computer Science majors take courses in algorithms, data structures, logic, programming languages, scientific computing, systems, and theory. Electives in artificial intelligence, computer graphics, computer vision, databases, multimedia, and networks are also possible. Requirements include:

- four semesters of calculus (MATH 191–192–293–294 or 111–122 (or 112)–221–222)
- two semesters of introductory computer programming (COM S 100 and ENGRD 211)
- a one-credit project (COM S 212)
- a seven-course computer science core (COM S 280, 312, 314, 321 or 322 or 421, 381, 414, and 482)
- two 400+ computer science electives, totaling at least six credits
- a computer science project course (COM S 413, 415, 418, 433, 473, 501, 514, 519, or 664)
- a mathematical elective course (ENGRD 270, MATH 300+, T&AM 310, etc.)
- two 300+ courses (field approved electives) that are technical in nature and total at least six credits
- a three-course specialization in a topic area other than computer science. These courses must be numbered 300-level or greater.

Note: All of the field electives described above must be courses of three or more credit hours, with the exception of the COM S project course, which is two credits or more.

The program is broad and rigorous, but it is structured in a way that supports in-depth study of outside areas. Intelligent course selection can set the stage for graduate study and employment in any technical area and any professional area such as business, law, or medicine. With the adviser, the computer science major is expected to put together a coherent program of study that supports career objectives and is true to the aims of liberal education.

Computer Science Honors Program

Eligibility

The Bachelor of Science degree *with honors* will be granted to students who, in addition to having completed the requirements for a bachelor degree, have:

- qualified for *latin* honors in the College of Engineering (basically, a cumulative GPA $\geq$ 3.5)
- at least eight credits of COM S course work at or above the 500-level (graded courses only; no seminars or two-credit project courses)
- at least six credits of COM S 490 (independent research) spread over two semesters, with a grade of A- or better each term.

See the COM S undergraduate web site for more information on eligibility: www.cs.cornell.edu/ugrad

Content

Honors courses may not be used to satisfy the COM S 400+ elective requirement, the COM S project requirement, the math or field approved electives, or the specialization.

Timing

Honors' determinations are made during the senior year. Students wanting to be considered for field honors should notify the Undergraduate Office in the Department of Computer Science via electronic mail at the following address: <ugrad@cs.cornell.edu>. The subject line for this message should read "HONORS TRACK." Related questions may be addressed to the ugrad e-mail alias, or candidates can call or stop by 303 Upson Hall, 255-0982.

Preparation

Arrangements for doing COM S 490 research should be made directly with faculty members in the department. Students are encouraged to discuss potential contacts with their advisers and/or browse the department's web page at www.cs.cornell.edu for specific leads on research opportunities. The Department of Computer Science reserves the right to make changes to the honors program requirements at any time. Generally speaking, all members of the same graduating class in COM S will be subject to the same honors criteria.

Minor in Computer Science

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the Computer Science minor: A&EP, BEE, CEE, CHEME, EAS, ECE, M&AE, MS&E, and OR&IE.

This minor is for students who anticipate that computer science will play a prominent role in their academic and professional career.

Requirements

To complete the minor, the student must take at least six (6) courses (18 credits minimum) chosen as follows:

I. Required Courses,

COM S/ ENGRD 211 Computers and Programming

COM S 321 Numerical Methods in Computational Biology

or COM S/ ENGRD 322 Introduction to Scientific Computing

or COM S 421 Numerical Analysis

COM S /ECE Computer Organization

II. Additional Courses

Three (3) COM S courses numbered 280 or higher (excluding seminars and COM S 490). Academic Standards: A letter grade of C or better for each course in the minor. S-U courses not allowed.

Note: Computing courses offered by other departments cannot be applied toward the Computer Science minor, with the exception of ECE 314. It is expected that all qualifying courses will be taken at Cornell for a letter grade. No substitutions allowed.

Engineering Minor in Information Science

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the Minor in Information Science: AEP, BEE, CEE, CHEME, COM S, EAS, ECE, M&AE, MSE, and OR&IE.

Information Science is an interdisciplinary field covering all aspects of digital information. The program has three main areas: information systems, human-centered systems, and social systems. Information systems studies the computer science problems of representing, storing, manipulating, and using digital information. Human-centered systems studies the relationship between humans and information, drawing from human-computer interaction and cognitive science. Social systems examines the economic, legal, political and social context. The minor has been designed to ensure that students have substantial grounding in all three of these areas in addition to having a working knowledge of basic probability and statistics necessary for analyzing data occurring in the real world.

Requirements

To complete the minor the student must take at least six (6) courses (18 credit minimum) chosen as follows:

- One statistics course
- Two courses from the information systems area (primarily computer science)
- One course from the human-centered systems area (human computer interaction and cognitive science)
- One course from the social systems area (social, economic, political and legal issues)
- One additional course from either the human-centered systems or the social systems areas

Statistics

ENGRD 270	Basic Engineering Probability and Statistics
CEE 304	Uncertainty Analysis in Engineering

Information Systems

COM S 230	Intermediate Web Design
COM S 330	Applied Database Systems
COM S 430	Information Discovery
COM S 432	Introduction to Database Systems
COM S 474	Introduction to Natural Language Processing
COM S 478	Machine Learning
COM S 502	Architecture of Web Information Systems and Digital Libraries
COM S 515	Public Policy and Security
ECE 562	Fundamental Information Theory
COM S 752	Seminar on Scholarly Information Architecture

Human-centered Systems

PSYCH 214	Cognitive Psychology (also COGST 214)
PSYCH 342	Human Perception: Applications to Computer Graphics, Art, and Visual Display (also COGST 342)
PSYCH 347	Psychology of Visual Communications
PSYCH 413	Information Processing: Conscious and Unconscious
COMM 439	Designing for Human-Computer Interaction
COMM 440	Computer Mediated Communication

Social Systems

STS 250	Technology in Society (also ENGR 250, HIST 250 and ECE 250)
STS 298	Inventing an Information Society (also ENGR 298 and ECE 298)
STS 387	The Automatic Lifestyle: Consumer Culture & Technology
STS 411	Knowledge, Technology, and Property
OR&IE 480	Information Technology
COMM 428	Communication Law
LAW 410	Limits on and Protection of Creative Expression - Copyright Law and Its Close Neighbors.

A grade of C or better is required for each course in the minor.

Master of Engineering (Computer Science) Degree Program

The M.Eng. program in computer science is a one-year program that can be started in either the fall or spring semester. This program is designed to develop expertise in system design and implementation in many areas of computer science, including computer networks, Internet architecture, fault-tolerant and secure systems, distributed and parallel computing, high performance computer architecture, databases and data mining, multimedia systems, computer vision, computational tools for finance, computational biology (including genomics), software engineering, programming environments, and artificial intelligence.

A typical program in computer science includes several upper-division and graduate courses and a faculty-supervised project. The course and project requirements are flexible and allow students to build up a program that closely matches their interests. In particular, slightly under half the courses may be taken outside the computer science department (for example, many students choose to take several business administration courses). Project work, which may be done individually or in a small group, can often be associated with ongoing research in the Department of Computer Science in one of the areas listed above.

Cornell seniors may use the *early admission option* to effectively co-register for the M.Eng. program while completing the undergraduate degree. This option can be started in either the fall or spring semester. It applies to students who have at least one credit and no more than eight credits remaining to complete their undergraduate program. All remaining undergraduate degree requirements must be satisfied by the end of the first semester the student is enrolled in the M.Eng. "early admit" program.

For more information about the M.Eng. program in computer science and the early admission option for Cornell seniors, please consult our web page at www.cs.cornell.edu/grad/meng.

Cooperative Program with the Johnson Graduate School of Management

Undergraduates majoring in computer science may be interested in a program that can lead, in the course of six years, to B.S., M.Eng. (Computer Science), and M.B.A. degrees. This program, which is sponsored jointly by the College of Engineering and the Johnson Graduate School of Management, enables students to study several subjects required for the M.B.A. degree as part of their undergraduate curriculum. Planning must begin early, however, if all requirements are to be completed on schedule.

For further details and assistance in planning a curriculum, students can consult with their adviser, the undergraduate office in 303 Upson Hall, or the Johnson School directly.

EARTH AND ATMOSPHERIC SCIENCES

(Formerly the Departments of Geological Sciences and part of Soil, Crop, and Atmospheric Sciences)

B. L. Isacks, chair; S. J. Riha, associate chair; Directors of Undergraduate Studies: K. H. Cook (Science of Earth Systems), R. W. Kay (Geological Sciences), and S. J. Colucci (Atmospheric Science); R. W. Allmendinger, W. D. Allmon, M. Barazangi, J. M. Bird, L. D. Brown, L. M. Cathles, J. L. Cisne, A. T. DeGaetano, L. A. Derry, P. J. Gierasch, C. H. Greene, D. L. Hysell, T. E. Jordan, S. Mahlburg Kay, M. C. Kelley, F. H. T. Rhodes, D. L. Turcotte, W. M. White, D. S. Wilks, M. W. Wysocki

Bachelor of Science Curriculum

We live on a planet with finite resources and a finite capacity to recover quickly from human-induced environmental stresses. It is also a powerful planet, with geologic hazards such as earthquakes, hurricanes, and volcanic eruptions that alter the course of history with little prior warning. As the human population grows, understanding the earth and its resources becomes progressively more important for both future policymakers and ordinary citizens. Because the human need to understand the earth is so pervasive, we provide our students with three tracks covering the spectrum of modern earth sciences.

The Department of Earth and Atmospheric Sciences offers an undergraduate engineering program which permits students to pursue one of three options leading to a B.S. degree in geological sciences: the geoscience option, the atmospheric science option, and the science of earth systems (SES) option. The geoscience option emphasizes the structure, composition, and evolution of our planet; the atmospheric science option covers the planetary processes producing weather and climate; and the SES option is concerned with processes on and near the earth's surface where the interactions of water, life, rock, and air produce our planetary environment. An engineering minor is available in one or a combination of these programs.

Atmospheric Science Option

Atmospheric science is the study of the atmosphere and the processes that shape weather and climate. The curriculum emphasizes the scientific study of the behavior of weather and climate, and applications to the important practical problems of weather forecasting and climate prediction. Students develop a fundamental understanding of atmospheric processes, and acquire skill and experience in the analysis, interpretation, and forecasting of meteorological events. The atmospheric science option satisfies both the curricular guidelines of the American Meteorological Society and the educational requirements of the National Weather Service for employment as a meteorologist, which also qualifies graduates for positions in private-sector forecasting and environmental consulting firms. The option also provides excellent preparation for graduate work in atmospheric science and related fields.

Students following the atmospheric science option are required to take ENGRD 270 as an engineering distribution course. The field program includes required introductory courses in atmospheric science (EAS 131) and EAS 250 (Instrumentation and Observations). Many of the upper division field courses require EAS 341 (Atmospheric Thermodynamics and Hydrostatics) and EAS 342 (Atmospheric Dynamics) as prerequisites, which are normally taken in the junior year. The additional required field program courses are EAS 331 (Climate Dynamics), EAS 352 (Synoptic Meteorology I), EAS 451 (Synoptic Meteorology II), EAS 435 (Statistical Methods in Meteorology), and EAS 447 (Physical Meteorology). Field-approved electives may be chosen from other EAS courses or from selected upper-division courses offered in other departments.

Geoscience Option

The geoscience option reveals Earth's turbulent history from the formation of our solar system to the plate tectonic cycles that dominate Earth's present behavior. That history is highlighted by the co-evolution of life and the Earth system—from the origin of life to the modern inter-glacial phase during which our species has so proliferated. Topics of study also include the fundamental processes responsible for earthquakes, volcanic eruptions, and mountain building. The geoscience option prepares students for advanced study in geology, geophysics, geochemistry, and geobiology, and careers in mineral and petroleum exploration or in environmental geology. Alternatively, it is a valuable major for a pre-law or pre-med program or in preparation for a career in K–12 education.

The geoscience option stresses a balanced overview of geology with considerable flexibility and a degree of specialization achieved by careful selection of field-approved electives. Students are required to take ENGRD/EAS 201 as an engineering distribution course. For students interested in geobiology or paleontology, BIO G 101/103–102/104 (or BIO G 109–110) are recommended. CHEM 208 may be substituted for PHYS 214.

The geoscience option requires the following courses: the introductory outdoor field course, EAS 210, and the five core courses, EAS 326, 355, 356, 375, and 388. Two additional EAS field-required courses and at least one field-approved elective must be EAS 300 through 600-level courses. The core courses may be taken in any reasonable sequence, except that EAS 355, which is offered in the fall, should be taken before EAS 356, which is offered in the spring. EAS 326, 355, 356, and 375 should be taken relatively early in the major program.

In addition, a requirement for an advanced outdoor field experience may be met by completing one of the following four-credit options: (a) EAS 417 (Field Mapping in Argentina, 3 credits) and EAS 491–492 (based on field observations) for a combined four-credit minimum; (b) EAS 437 (Geophysical Field Methods, 3 credits) plus at least one credit of EAS 491 or 492 using geophysical techniques from EAS 437; (c) EAS 491–492 (Undergraduate Research, two credits each) with a significant component of field work; or (d) an approved outdoor field course taught by another college or university (four-credit minimum).

A selection of field-approved electives may provide specializations in geophysics, geochemistry (including petrology and mineralogy), geobiology (paleontology), and geology applied to mineral and petroleum industries, environmental problems, hydrology, and civil engineering. Students intending to specialize in economic geology or pursue careers in the mining industries or mineral exploration should consider including economics courses among their liberal studies distribution courses. Students who want a more general background or want to remain uncommitted with regard to specialty must choose at least two of their field-approved electives from the same field. The field-approved electives outside the field may be chosen from offerings in other science or engineering fields or the liberal arts, but should be at the 300-level or above. Students may request substitution of EAS 491 and 492, Undergraduate Research, for a fourth-year field-approved elective but not if it is being used to fulfill the outdoor field requirement.

In addition to course work, students learn by involvement in research projects. Facilities include equipment for processing seismic signals and digital images of the earth's surface, instruments for highly precise isotope and element analyses, and extensive libraries of earthquake records, satellite images, and exploration seismic records. High-pressure, high-temperature mineral physics research uses the diamond anvil cell and the Cornell High Energy Synchrotron Source (CHESS). Undergraduates have served as field assistants for faculty members and graduate students in Argentina, British Columbia, the Aleutian Islands, Scotland, Switzerland, Tibet, and Barbados. Undergraduates are encouraged to participate in research activities, frequently as paid assistants.

Science of Earth Systems (SES) Option

The science of earth systems (SES) option provides an integrated view of Earth processes critical to the understanding of our environment. This scientific understanding is the primary foundation used to determine to what degree human societies can modify or adapt to future change. The SES option is for students interested in careers and/or graduate study in any of the earth system sciences or a future in environmental law, environmental engineering, science teaching, or environmental public policy. The SES option enables students in the College of Engineering to take part in the multi-disciplinary, intercollege program in the Science of Earth Systems. Collaborations with other departments provide breadth and depth to the program.

The SES option emphasizes a strong preparation in basic mathematics and sciences and an integrated approach to the study of the Earth system including the lithosphere, biosphere, hydrosphere, and atmosphere. Students are required to take a second semester of chemistry, two semesters of introductory biology, and ENGRD 201 (Physics and Chemistry of the Earth) as one of the engineering distribution courses. The option requires a set of three core courses, normally taken in the junior or senior years, which provide breadth and integration. An additional set of five intermediate to advanced courses are selected to provide depth and a degree of specialization. These courses permit the student to specialize in such areas as climate dynamics, biogeochemistry, ocean sciences, environmental geosciences, ecological systems, hydrological sciences, and soil sciences.

The field requirements for the SES option are summarized as follows. CHEM 208 and ENGRD 201/EAS 201 are required. The field program includes BIO G 101/103–102/104 (or BIO G 109–110), BIOES 261, the three SES core courses listed below, five additional courses selected with the adviser's approval to provide specialization in one or a combination of the areas covered by SES, and an additional field-approved elective. Two of the specialization courses will count as field-required courses, and three as field-approved electives. At least three of the field-approved electives must be non-EAS courses. The three SES core courses are:

EAS 302 Evolution of the Earth System—Spring. 4 credits

EAS 321 Biogeochemistry (also NTRES 321)—Fall. 4 credits

EAS 331 Climate Dynamics (also ASTRO 331)—Fall. 4 credits

Areas of specialization include (but are not limited to) the following:

- Biogeochemistry
- Climate dynamics
- Ecological systems
- Environmental biophysics
- Environmental geology
- Hydrological sciences
- Soil science
- Ocean sciences

In addition to faculty in or associated with the Department of Earth and Atmospheric Sciences, faculty currently associated with the SES program include the following:
W. Brutsaert (CEE); L. Hedin (EEB);
R. Howarth (EEB, EAS); J.-Y. Parlange (BEE);
J. Yavitt (NTRES).

Earth and Atmospheric Science Honors Program

Eligibility

The Bachelor of Science degree (in geological sciences) with honors will be granted to students who, in addition to having completed the requirements for a bachelor's degree, have satisfactorily completed the honors program in Earth and Atmospheric Sciences and have been recommended for the degree by the honors committee of the department. An honors program student must enter with and maintain a cumulative GPA $\geq$ 3.5.

Content

In addition to the minimum requirements, a student must

1. take at least nine credits above the minimum required for graduating and approved by the upperclass adviser;
2. have a written proposal of the honors project accepted by his or her faculty adviser and the director of undergraduate studies;
3. complete an honors thesis involving research (EAS 491–492 or 499, two or more credits each) of breadth, depth, and quality.

Timing

A student interested in completing an honors thesis must, by the beginning of the seventh semester, have a written proposal of the honors project accepted by the student's adviser and the director of undergraduate studies.

Procedures

Each applicant to the Earth and Atmospheric Sciences honors program must have a faculty adviser to supervise the honors thesis research. Written approval by the faculty member who will direct the research is required. After the college verifies the student's grade-point average, the student will be officially enrolled in the honors program.

Minor in Geological Sciences

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the Geological Sciences minor: BEE, A&EP, CEE, CHEME, COM S, ECE, M&AE, MS&E, OR&IE.

Whereas many engineering students will encounter and have to understand the natural operating systems of Earth in their professions, the tools and techniques used by earth scientists to understand these solid and fluid systems over the widest scales of space and time are of use to a wide cross-section of engineering students. This minor is designed to give a flexible set of options for students looking to complement training in their major field with a core education in Geological Sciences.

The requirements for the Geological Sciences minor are outlined below. For further details consult the Undergraduate Programs Office, 2122 Snee Hall, or www.eas.cornell.edu.

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits), chosen as follows:

I. Choose one or two of these three courses:

   ENGRD 201 Introduction to the Physics and Chemistry of the Earth

   EAS 210 Introduction to Field Methods in Geological Sciences

   EAS 203 Natural Hazards and the Science of Complexity

II. Choose at least two courses from the following list of core courses:

   EAS 302 Evolution of the Earth System

   EAS 321 Introduction to Biogeochemistry

   EAS 326 Structural Geology

   EAS 355 Mineralogy

   EAS 356 Petrology and Geochemistry

   EAS 375 Sedimentology and Stratigraphy

   EAS 388 Geophysics and Geotectonics

III. To complete the minor, these three to four courses are to be supplemented with two to three additional EAS courses at the 300-level or higher. These may include, for example, additional courses from the above list of core courses, undergraduate research courses, and outdoor field courses.

Academic Standards: A letter grade of C- or better for each course in the minor and a cumulative GPA of 2.0 or better for all courses in the minor.

ELECTRICAL AND COMPUTER ENGINEERING

C. R. Pollock, director; C. E. Seyler, associate director; S. B. Wicker, associate director; A. B. Apsel, J. M. Ballantyne, T. Berger, A. W. Bojanczyk, M. Burtscher, H.-D. Chiang, D. F. Delchamps, L. F. Eastman, D. T. Farley, T. L. Fine, Z. Haas, D. A. Hammer, M. Heinrich, S. S. Hemami, C. R. Johnson, Jr., E. Kan, M. C. Kelley, P. M. Kintner, R. Kline, K. T. Kornegay, J. P. Krusius, A. Lal, M. Lipson, R. Manohar, S. A. McKee, B. A. Minch, T. W. Parks, C. R. Pollock, A. P. Reeves, A. Scaglione, S. Servetto, J. R. Shealy, E. Speight, M. G. Spencer, C. L. Tang, R. J. Thomas, S. Tiwari, L. Tong

Bachelor of Science Curriculum

The Department of Electrical and Computer Engineering offers an undergraduate field program which leads to a B.S. degree in electrical and computer engineering. The curriculum provides a foundation which reflects the broad scope of this engineering discipline.

Concentrations include computer engineering and digital systems; control systems; electronic circuit design; information, communication, and decision theory; microwave electronics; plasma physics; power and energy systems; quantum and optical electronics; radio and atmospheric and space physics; and semiconductor devices and applications.

Electrical and Computer Engineering Field Program

Students planning to enter the field program in Electrical and Computer Engineering must take ENGRD 230 as an engineering distribution course. The fall of the sophomore year is the preferred term for ENGRD 230 for students without advanced standing in mathematics. Electrical and Computer Engineering students with an interest in computer engineering are encouraged to take ENGRD 211 as an engineering distribution course prior to entry into the field program. In addition, the field program normally begins in the spring of the sophomore year, as shown below. All of these courses (except ECE 210 and ENGRD 230) are taught only once each academic year, either spring or fall, as indicated in the course descriptions.

Course	Credits
Field Required Courses	
ECE 210, Introduction to Circuits for Electrical and Computer Engineers	4
ENGRD 230, Introduction to Digital Logic Design	4
ECE 301, Signals and System I	4
ECE 303, Electromagnetic Fields and Waves	4
ECE 314, Computer Organization	4
ECE 315, Introduction to Microelectronics	4
Field Approved Electives (32-credit minimum in the following categories)	
Advanced Electrical and Computer Engineering Electives† (7 lecture courses)	20 minimum
Outside ECE Electives‡ (3 courses)	9 minimum
Total minimum field credits	52

ECE 310 can be taken in place of ENGRD 270 or T&AM 310 to satisfy the college application of probability and statistics requirement.

†These electives must include two 400-level electrical and computer engineering culminating design experience (CDE) courses and at least two additional courses at the 400-level or above. The remaining electives may not include independent project courses, such as ECE 391, 392, 491, or 492, and must be at the 300-level or above in Electrical and Computer Engineering.

Courses that meet the CDE requirement are described in the online ECE Handbook. (The list is dynamic and changes frequently. Always refer to the latest information on the ECE Web Handbook.) All courses must have a college-level prerequisite.

‡Must include one course at the 300-level or above (see *Electrical and Computer Engineering Web Handbook* for details).

All students graduating with a B.S. degree must fulfill the engineering design requirement and the college technical writing requirement. Two culminating design experience (CDE) courses (4 credits each) satisfy the engineering design requirement. The technical writing requirement is discussed in the College of Engineering section of this book.

Undergraduate specialization is achieved through the various electrical and computer engineering elective courses, as well as other courses in related technical fields within engineering, mathematics, the physical sciences, and the analytical biological sciences. The School of Electrical and Computer Engineering offers more than 30 courses that are commonly taken as electives by undergraduates.

An electrical and computer engineering honors program also exists for those students who apply between their fifth and sixth semester and meet the program entrance requirements. The honors program requires an additional senior ECE course; a required senior year directed reading course, a design project, or ENGRG 470; and completion of the honors seminar in the junior year. Details are available via the electrical and computer engineering homepage located through the web at www.ece.cornell.edu/UgradHandbook/honors.html.

All students majoring in electrical and computer engineering are expected to meet the following academic standards:

1. Students must achieve a grade-point average of at least 2.3 every semester.
2. No course with a grade of less than C– may be used to satisfy degree requirements in the field program or serve as a prerequisite for a subsequent electrical and computer engineering course.
3. Students must complete satisfactorily ECE 210, MATH 294, and PHYS 214 by the end of the sophomore year in the field program of Electrical and Computer Engineering, and make adequate progress toward the degree in subsequent semesters.
4. Honors program students must meet the GPA and progress requirements specified in the *Electrical and Computer Engineering Web Handbook* and the college handbook to remain active participants.

Electrical and Computer Engineering Honors Program

Eligibility, Entry, and Continuation

A student must apply to enter the ECE Honors Program and may do so as early as the beginning of the fifth semester or as late as the end of the sixth semester. A student must have a cumulative GPA of at least 3.5 to apply for entry. A student in the honors program whose cumulative GPA falls below 3.5 at the end of any semester will be dropped from the honors program by College of Engineering regulations. There is an additional requirement (see Honors Seminar) for entry into the program after the end of the fifth semester.

Honors Seminar

Any student in the honors program is required to take (or to have taken) an honors seminar during his or her junior year. The Honors Seminar is a two-credit semester-course (offered spring only) consisting of a weekly series of introductory research lectures by Electrical and Computer Engineering faculty members. Each honors seminar enrollee will be required to write a number of short papers on topics covered in the lecture series. Many Electrical and Computer Engineering faculty members will give a lecture or short series of lectures as part of the Honors Seminar. Students in the honors program and students with a cumulative GPA of at least 3.5 who are considering entering the honors program must receive letter grades for the Honors Seminar.

Honors Project

Any student in the honors program is required to accumulate at least three credit hours from a senior year honors project consisting either of design, ENGRG 470, or directed reading. All honors projects emphasize the development of communication skills. Design- and reading-oriented honors projects require explicitly a written submission summarizing and concluding the project.

Additional Coursework

Any student in the honors program is required to take at least three credit hours of advanced (senior level) ECE coursework that has at least a 300-level prerequisite. These credit hours are in addition to any credit hours required as part of the ECE field program.

The program described above requires honors program participants to amass at least nine credit hours over and above the 128 credit hours required for a B.S. degree; thus an honors degree requires a minimum of 137 credit hours.

Minor in Electrical and Computer Engineering

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the Electrical and Computer Engineering minor: BEE, A&EP, CEE, CHEME, COM S, EAS, M&AE, MS&E*, OR&IE. (*MS&E students planning to pursue this minor must receive prior written approval from both MS&E and ECE, via petition.)

The School of Electrical and Computer Engineering offers a minor to students who wish to complement their major field by obtaining a background in electrical and computer engineering. The minor offers the opportunity to study analog and digital circuits, signals and systems, electromagnetic fields, and additionally specialize at higher levels in one of several different areas such as circuit design, electronic devices, communications, computer engineering, networks, or space engineering.

The requirements for the Electrical and Computer Engineering minor are outlined below. For further details consult the Electrical and Computer Engineering Undergraduate Programs Office, 222 Phillips Hall.

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits), chosen as follows:

I. Required Courses:

ECE/ENGRD 210 Introduction to Circuits for Electrical and Computer Engineers (4 credits)

ENGRD 230 Introduction to Digital Logic Design

II. Two of the following:

ECE 301 Signals and Systems I

ECE 303 Electromagnetic Fields and Waves

ECE 315 Introduction to Microelectronics

III. One other ECE course at the 300 level or above (3 credit minimum)

IV. One other ECE course at the 400 level or above (3 credit minimum)

Academic Standards: A letter grade of C- or better for each course to be counted in the minor and a cumulative GPA of 2.3 or better for all courses in the minor.

Master of Engineering (Electrical) Degree Program

The M.Eng. (Electrical) degree program prepares students either for professional work in electrical and computer engineering and closely related areas or for further graduate study in a doctoral program. The M.Eng. degree differs from the Master of Science degree mainly in its emphasis on professional skills, engineering design, and analysis skills rather than basic research.

The program requires 30 credits of advanced technical course work beyond that expected in a typical undergraduate program, including a minimum of four courses in electrical and computer engineering. An electrical and computer engineering design project is also required and may account for three to eight credits of the M.Eng. program. Occasionally, students take part in very extensive projects and may apply for a waiver of the eight-credit maximum and increase the project component to 10 credits. Students with special career goals, such as engineering management, may apply to use up to 11 credits of approved courses that have significant technical content, but are taught in disciplines other than engineering, mathematics, or the physical sciences.

Cornell undergraduate students with advanced standing frequently take one or more graduate-level courses prior to graduation and may actually begin accumulating credit toward the Master of Electrical and Computer Engineering program in their last semester of undergraduate work. Application of credits taken while an undergraduate at Cornell must be approved in advance of the last semester of undergraduate work.

Although admission to the M.Eng. (Electrical) program is highly competitive, all well-qualified students are urged to apply. Further information is available from the Master of Electrical and Computer Engineering Program web site at www.ece.cornell.edu/meng/index.html.

MATERIALS SCIENCE AND ENGINEERING

C. K. Ober, director, D. G. Ast, S. P. Baker, J. M Blakely, R. Dieckmann, E. P. Giannelis, D. T. Grubb, G. G. Malliaras, A. L. Ruoff, S. L. Sass, Y. Suzuki, M. O. Thompson, U. B. Wiesner

Bachelor of Science Curriculum

Students majoring in materials science and engineering are required to take ENGRD 261, or ENGRD 262, before affiliating with the field. It is strongly recommended that these courses be taken as an engineering distribution during the sophomore year. The field program develops a comprehensive understanding of the physics and chemistry underlying the unique properties of modern engineering materials and processes.

In the field, students are required to complete a series of electives to develop both breadth and specialization in sub-areas of the field including, for example, solid state, metallic materials, ceramic materials, polymeric materials, electronic materials, biomaterials, or computational materials science. These requirements are satisfied through a series of technical electives in the junior and senior years, selected from multiple engineering and science departments. Optional research involvement courses provide undergraduates with the opportunity to work with faculty members and their research groups on current projects.

The requirements for a Bachelor of Science degree in materials science and engineering are:

1. Completion of the common engineering curriculum including liberal studies electives
2. ENGRD 261, Mechanical Properties of Materials: From Nanodevices to Superstructures OR ENGRD 262, Electronic Material for the Information Age

3. Completion of 12 required field courses:

   ENGRD 202 Mechanics of Solids

   MS&E 204 Materials Chemistry

   MS&E 206 Atomic and Molecular Structure of Matter

   MS&E 302 Mechanical Properties of Materials, Processing, and Design

   MS&E 303 Thermodynamics of Condensed Systems

   MS&E 304 Kinetics, Diffusion, and Phase Transformations

   MS&E 305 Electronic Structure of Matter

   MS&E 306 Electronic, Optical and Magnetic Properties of Materials

   MS&E 307 Materials Design Concepts I

   MS&E 403/405 Senior Materials Lab I or Senior Thesis I

   MS&E 404/406 Senior Materials Lab II or Senior Thesis II

   MS&E 407 Materials Design Concepts II

4. Depth in one specialization developed through three technical electives
5. Breadth developed through two technical electives in different specialization areas
6. One of the depth or breadth electives must be taken from outside MS&E
7. One additional outside technical elective

To continue in good standing in the Field of Materials Science and Engineering, students must

1. Maintain a 2.0 term average for all semesters.
2. Maintain an average of 2.3, with no grade below C, in the department's core curriculum.
3. Complete ENGRD 261 or ENGRD 262 with a minimum of C prior to affiliation.

The department's core curriculum consists of ENGRD 261, or ENGRD 262 the 12 required field courses, and the five technical electives constituting the depth and breadth requirements.

An attractive and very challenging program combines the materials science and engineering curriculum with that of either electrical engineering or mechanical engineering, leading to a double major. Curricula leading to the double-major degree must be approved by both of the departments involved and students are urged to plan such curricula as early as possible to avoid scheduling conflicts.

Materials Science and Engineering Honors Program

Eligibility

The Bachelor of Science degree with honors will be granted to students who, in addition to having completed the requirements for a bachelor degree, have satisfactorily completed the honors program in materials science and engineering and have been recommended for the degree by the honors committee of the department. An honors program student must enter with, and maintain, a cumulative GPA above 3.5.

Content

The requirements for an honors degree in materials science and engineering are:

1. Students must complete at least nine credits beyond the minimum required for graduation in materials science and engineering. This increases the minimum number of credits for graduation with honors to 137. These additional courses must be technical in nature, i.e., in engineering, mathematics, chemistry, and physics at the 400- and graduate-level, with selected courses at the 300-level. All courses satisfying this requirement must be approved by the upper class adviser.
2. Senior honors thesis (MS&E 405/406) with a grade of at least A.

Note: Undergraduates typically enter the honors program at the beginning of their senior year (seventh semester) and thus must have a cumulative GPA equal to or greater than 3.5 at that point.

Timing

All interested students must complete a written application no later than the end of the third week of the first semester of their senior year, but are encouraged to make arrangements with a faculty member to work on a senior honors thesis during the second semester of their junior year. A student must be in the program for at least two semesters prior to graduation.

Procedures

Each application to the materials science and engineering honors program must have a faculty adviser to supervise the honors program. Written approval of the faculty member who will direct the research is required. After the student's grade-point average is verified, the student will be officially enrolled in the honors program.

Minor in Materials Science and Engineering

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the materials science and engineering minor: BEE, A&EP, CEE, CHEME, COM S, EAS, ECE, M&AE, OR&IE.

Material properties are the foundation of many engineering disciplines including mechanical, civil, chemical, and electrical engineering. This minor provides engineers in related fields with a fundamental understanding of mechanisms that determine the ultimate performance, properties, and processing characteristics of modern materials.

The requirements for the materials science and engineering minor are outlined below. For further details, consult the Materials Science and Engineering Undergraduate Program Office, 210 Bard Hall.

Requirements

To complete the minor, students must take at least six courses (minimum of 18 credits), chosen as follows:

1. ENGRD 261 Mechanical Properties of Materials: From Nanodevices to Superstructures OR ENGRD 262, Electronic Materials for the Information Age
2. Two of:

   MS&E 204 Materials Chemistry

   MS&E 206 Atomic and Molecular Structure of Matter

   MS&E 302 Mechanical Properties of Materials, Processing, and Design

   MS&E 303 Thermodynamics of Condensed Systems

   MS&E 304 Kinetics, Diffusion, and Phase Transformations

   MS&E 305 Electronic Structure of Matter

   MS&E 306 Electronic, Optical, and Magnetic Properties of Materials

3. Three electives chosen from:

Any MS&E course at the 300-level or above.

Selected courses in materials properties and processing (at the 300-level or above) from A&EP, CHEME, CEE, ECE, M&AE, PHYS, and CHEM, as approved by the MS&E undergraduate coordinator.

Academic Standards: A letter grade of C or better for each course in the minor.

Master of Engineering (Materials) Degree Program

Students who have completed a four-year undergraduate program in engineering or the physical sciences can be considered for admission into the M.Eng. (Materials) program. This program consists of 30 credits, including course work and a master's design project. The project, which requires individual effort and initiative, is carried out under the supervision of a faculty member. Twelve credits are devoted to the project, which is normally experimental in nature, although computational or theoretical projects are also possible.

Courses for the additional 18 credits are selected from the graduate-level classes in materials science and engineering and from other related engineering fields approved by the faculty. Typically half of the courses are from MS&E. One three-credit technical elective must include advanced mathematics (modeling, computer application, or computer modeling), beyond the MS&E undergraduate requirements.

MECHANICAL AND AEROSPACE ENGINEERING

S. Leibovich, director; P. L. Auer, C. T. Avedisian, D. L. Bartel, J. F. Booker, J. R. Callister, M. E. Campbell, D. A. Caughey, L. R. Collins, R. D'Andrea, P. R. Dawson, P. C. T. deBoer, E. M. Fisher, E. Garcia, A. R. George, F. C. Gouldin, C. Hui, H. Lipson, M. Y. Louge, J. L. Lumley, M. P. Miller, F. C. Moon, F. K. Moore, S. Mukherjee, R. M. Phelan, S. L. Phoenix, S. B. Pope, M. L. Psiaki, E. L. Resler, Jr., A. Ruina, W. Sachse, S.E. Shen, K. E. Torrance, F. Valero-Cuevas, M. C. H. van der Meulen, H. B. Voelcker, K. K. Wang, Z. Warhaft, C. H. K. Williamson, N. Zabaras, A. Zehnder

Members of the faculty of the graduate Fields of Aerospace Engineering and Mechanical Engineering are listed in the *Announcement of the Graduate School.*

Bachelor of Science Curriculum in Mechanical Engineering

The upperclass field program in Mechanical Engineering is designed to provide a broad background in the fundamentals of this discipline as well as to offer an introduction to the many professional and technical areas with which mechanical engineers are concerned. The program covers both major streams of the field of mechanical engineering.

Mechanical systems, design, and materials processing is concerned with the design, analysis, testing, and manufacture of machinery, vehicles, devices, and systems. Particular areas of concentration are mechanical design and analysis, vehicle engineering, biomechanics, and materials processing and precision engineering. Other topics covered are computer-aided design, vibrations, control systems, and dynamics.

Engineering of fluids, energy, and heat-transfer systems is concerned with the efficient conversion of energy in electric power generation and aerospace and surface transportation, the environmental impact of engineering activity (including pollutants and noise), aeronautics, and with the experimental and theoretical aspects of fluid flow, heat transfer, thermodynamics, and combustion. Specific areas of concentration include aerospace engineering; heat, energy, and power engineering; and thermo-fluid sciences.

The undergraduate program is a coordinated sequence of courses beginning in the sophomore year. During the fall term sophomore students who plan to enter the Mechanical Engineering program take ENGRD 202 (also T&AM 202) as an engineering distribution course. They also are encouraged to take ENGRD 221 (also M&AE 221), which is a field requirement that may simultaneously satisfy Common Curriculum requirements as an engineering distribution course. Occasionally because of study abroad or requirements for second majors or pre-med, students cannot complete all of the required sophomore courses on schedule. In such cases students should delay ENGRD 221 until the first semester of the junior year. The Sibley School supports students with unusual requirements, but any delays or substitutions must be discussed with and receive approval from the student's adviser.

The course requirements for the degree of Bachelor of Science in Mechanical Engineering are as follows:

1. Completion of the Common Curriculum. During the upperclass years this will typically mean earning credit for five humanities or social science courses.
2. Completion of the field requirements, which consist of eleven required courses (beyond ENGRD 202 already mentioned), and five field approved elective courses.

The eleven required courses are:

M&AE 212, Mechanical Properties and Processing of Engineering Materials

M&AE 221, Thermodynamics

M&AE 225, Mechanical Design and Synthesis

T&AM 203, Dynamics

ECE 210, Introduction to Circuits for Electrical and Computer Engineers

M&AE 323, Introductory Fluid Mechanics

M&AE 324, Heat Transfer

M&AE 325, Mechanical Design and Analysis

M&AE 326, System Dynamics

M&AE 427, Fluids/Heat Transfer Laboratory

M&AE 428, Engineering Design

Electives

Students should use the flexibility provided by the field approved electives, approved electives, and humanities/social sciences electives to develop a program to meet their specific goals.

Field Approved Electives

The upper-level program includes five field approved electives. Using these five courses, the student must satisfy the following requirements.

At least three of the courses must be upper-level (300+) M&AE courses. Of these three, two must satisfy a concentration chosen by the student. Typically these are two courses chosen from an appropriate subset of the school's upper-class offering. However, students may petition for approval of two related courses to form a custom concentration.

The standard concentrations are:

Fluids/Aerospace Engineering, M&AE 305, 306, 423, 506, 507

Thermal Systems Engineering, M&AE 423, 449, 453, 506, 543

Materials Processing, M&AE 412, 514

Mechanical Systems, M&AE 412, 417, 470, 478, 479, 525, 565

Vehicle Engineering, M&AE, 306, 386, 425, 426, 440, 441, 449, 486, 506, 507

Biomechanics, M&AE 463, 464, 565

Of the three upper-level M&AE courses, one must be an approved design elective. The design offerings may change from year to year.

Typically this list includes M&AE 401, 412, 426, 441, 470, 479, 486, 491 and 525.

Note that the design elective must be taken during the senior year. Note that a single course may satisfy both the design and concentration requirements, in which case the third course could be any upper level M&AE course.

One of the courses must be an approved upper-level mathematics course taken after MATH 294. The course must include some material on statistics. Currently, the approved courses are T&AM 310, OR&IE 270, and CEE 304.

One of the field approved electives can be viewed as a technical elective and may be any course at an appropriate level, chosen from engineering, mathematics, or science (physics, chemistry, or biological sciences). Appropriate level is interpreted as being at a level beyond the required courses of the college curriculum. Note that courses in economics, business, and organizational behavior are not accepted. Advisers may approve such courses as approved electives.

Approved Electives

To maximize flexibility (i.e., the option for study abroad, COOP, internships, pre-med, and flexibility during the upper-class years), the Sibley School faculty recommends that students delay use of approved electives until after term three. The faculty encourages students to consider the following as possible approved electives:

any engineering distribution course

courses stressing oral or written communications

courses stressing the history of technology

rigorous courses in the physical sciences (physics, biology, chemistry)

courses in informational science (mathematics, computer science)

courses in methodologies (modeling, problem solving, synthesis, design)

courses in technology (equipment, machinery, instruments, devices, processes)

courses in business enterprise operations (economics, financial, legal, etc.)

courses in organizational behavior

courses in cognitive sciences.

The faculty recommendation on humanities/ social sciences electives is that students build a program that includes studies in:

history of technology

societal impacts of technology

history

foreign languages

ethics

communications

political science

aesthetics

economics

architecture

An additional graduation requirement of the field program is proof of elementary competence in computer-aided design and technical drawing. The demonstration of competence is expected before completion of the first four weeks of M&AE 225, Mechanical Synthesis. This proof may be given in a number of ways, including satisfactory completion of

a. A course with computer-aided design with technical drawing in high school or in a community college,
b. ENGRG 102, Drawing and Engineering Design,
c. another computer-aided design and technical drawing course at Cornell, or
d. a departmental examination.

The computer applications requirement of the Common Curriculum may be satisfied by several courses, including M&AE 423, M&AE 453, M&AE 470 and M&AE 479.

The technical writing requirement of the Common Curriculum is satisfied by M&AE 427.

Introduction to Circuits for Electrical and Computer Engineers (ECE 210) may be replaced or supplemented by Electronic Circuits (PHYS 360).

A limited set of third-year courses is offered each summer under the auspices of the Engineering Cooperative Program.

More detailed materials describing the Mechanical Engineering Program can be obtained from the Sibley School of Mechanical and Aerospace Engineering, Upson Hall.

Minor in Mechanical Engineering

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the mechanical engineering minor: BEE, A&EP, CHEME, CEE, COM S, EAS, ECE, MS&E, OR&IE.

Requirements

To complete the minor, the student must choose at least six courses (minimum of 18 credits) from among the following: M&AE courses at the 200-level or above; ENGRD 202, Mechanics of Solids; ENGRD 203, Dynamics.

Rules for selecting courses:

(1) The selection of courses must satisfy the following three requirements.

a) At least two courses must be numbered above 300.

b) At least one course must be either (1) numbered above 500 or (2) numbered above 326 and have as its prerequisite ENGRD 202, ENGRD 203, or an M&AE course.

c) Each course must be worth at least three credits.

(2) Substitutions of courses other than M&AE (or ENGRD 202 and 203) will not be accepted as part of the M&AE minor. However, some instructors of M&AE courses will accept non-M&AE courses as substitute prerequisites for their courses, or may choose to waive prerequisites in some circumstances. Students should check with the course instructor.

Academic Standards: A letter grade of C- or better for each course in the minor.

Examples of typical minor programs are as follows:

Typical focus in Fluids/Thermal Systems:

The following four courses:

ENGRD 202 Mechanics of Solids

ENGRD 203 Dynamics

ENGRD 221 Thermodynamics

M&AE 323 Introductory Fluid Mechanics

Plus two of the following, of which at least one course must satisfy requirement 1b:

M&AE 305 Introduction to Aeronautics

M&AE 324 Heat Transfer

M&AE 423 Intermediate Fluid Dynamics

M&AE 427 Fluids/Heat Transfer Laboratory

M&AE 449 Combustion Engines

M&AE 490 Special Investigations in Mechanical and Aerospace Engineering

M&AE 491 Design Projects in Mechanical and Aerospace Engineering

M&AE 506 Aerospace Propulsion Systems

M&AE 507 Dynamics of Flight Vehicles

M&AE 543 Combustion Processes

Typical focus in Mechanical Systems/Design:

The following two courses:

ENGRD 202 Mechanics of Solids

ENGRD 203 Dynamics

One or more of the following:

M&AE 212 Mechanical Properties and Processing of Engineering Materials

M&AE 225 Mechanical Design and Synthesis

M&AE 325 Mechanical Design and Analysis

M&AE 326 System Dynamics

The remainder from this list, of which at least one course must satisfy requirement 1b:

M&AE 306 Spacecraft Engineering

M&AE 386/486 Automotive Engineering

M&AE 412 Smash and Crash: Mechanics of Large Deformations

M&AE 417 Introduction to Robotics: Dynamics, Control, Design

M&AE 464 Design for Manufacture

M&AE 478 Feedback Control Systems

M&AE 490 Special Investigations in Mechanical and Aerospace Engineering

M&AE 491 Design Projects in Mechanical and Aerospace Engineering

M&AE 514 Design for Manufacture and Assembly

M&AE 565 Biomechanical Systems—Analysis and Design

M&AE 571 Applied Dynamics

Preparation in Aerospace Engineering

Although there is no separate undergraduate program in aerospace engineering, students may prepare for a career in this area by majoring in mechanical engineering and taking courses from the aerospace engineering concentration such as M&AE 305, 306, 506, and 507. Students may prepare for the graduate program in aerospace engineering by majoring in mechanical engineering, in other appropriate engineering specialties such as electrical engineering or engineering physics, or in the physical sciences. Other subjects recommended as preparation for graduate study include thermodynamics, fluid mechanics, applied mathematics, chemistry, and physics.

Master of Engineering (Aerospace) Degree Program

The M.Eng. (Aerospace) degree program provides a one-year course of study for those who wish to develop a high level of competence in engineering science, current technology, and engineering design.

The program is designed to be flexible so that candidates may concentrate on any of a variety of specialty areas. These include aerodynamics, acoustics and noise, turbulent flows, non-equilibrium flows, combustion, dynamics and control, computational fluid dynamics, etc.

A coordinated program of courses for the entire year is agreed upon by the student and the faculty advisor. Any subsequent changes must also be approved by the committee. An individual student's curriculum includes a four- to eight-credit design course, a minimum of 12 credits in aerospace engineering or a closely related field, and sufficient technical electives to meet the total degree requirement of 30 credits (of which at least 28 credits must have letter grades).

The design projects may arise from individual faculty and student interests or from collaboration with industry. All projects must have an aerospace engineering design focus and have the close supervision of a faculty member.

All courses must be of true graduate nature. In general, all courses must be beyond the level of those required in an undergraduate engineering program; credit may be granted for an upper-level undergraduate course if the student has done little or no previous work in that subject area, but such courses must have the special approval of the M&AE Master of Engineering Committee.

The technical electives may be courses of appropriate level in mathematics, physics, chemistry, or engineering; a maximum of six credits may be taken in areas other than these if the courses are part of a well-defined program leading to specific professional objectives. It is expected that all students will use technical electives to develop proficiency in mathematics beyond the minimum required of Cornell engineering undergraduates if they have not already done so before entering the program. Courses in advanced engineering mathematics or statistics are particularly recommended.

Students should check with the M&AE graduate field office (104 Upson Hall) for additional degree requirements.

Master of Engineering (Mechanical) Degree Program

The M.Eng. (Mechanical) degree program provides a one-year course of study for those who wish to develop a high level of competence in engineering science, current technology, and engineering design.

The program is designed to be flexible so that candidates may concentrate on any of a variety of specialty areas. These include biomechanical engineering, combustion, propulsion and power systems, fluid mechanics, heat transfer, materials and manufacturing engineering, mechanical systems and design, etc.

A coordinated program of courses for the entire year is agreed upon by the student and the faculty advisor. Any subsequent changes must also be approved by the committee. An individual student's curriculum includes a four- to eight-credit design course, a minimum of 12 credits in mechanical engineering or a closely related field, and sufficient technical electives to meet the total degree requirement of 30 credits (of which at least 28 credits must have letter grades).

The design projects may arise from individual faculty and student interests or from collaboration with industry. All projects must have a mechanical engineering design focus and have the close supervision of a faculty member.

All courses that constitute the major concentration must be of true graduate nature. In general, all courses must be beyond the level of those required in an undergraduate engineering program; credit may be granted for an upper-level undergraduate course if the student has done little or no previous work in that subject area, but such courses must have the special approval of the M&AE Master of Engineering Committee.

The technical electives may be courses of appropriate level in mathematics, physics, chemistry, or engineering; a maximum of six credits may be taken in areas other than these if the courses are part of a well-defined program leading to specific professional objectives. It is expected that all students will use technical electives to develop proficiency in mathematics beyond the minimum required of Cornell engineering undergraduates if they have not already done so before entering the program. Courses in advanced engineering mathematics or statistics are particularly recommended.

Students should check with the M&AE graduate field office (104 Upson Hall) for additional degree requirements.

Students enrolled in the M.Eng. (Mechanical) degree program may take courses that also satisfy the requirements of the manufacturing, energy, or electronic packaging option programs leading to special dean's certificates in those areas.

NUCLEAR SCIENCE AND ENGINEERING

Faculty members in the graduate Field of Nuclear Science and Engineering who are most directly concerned with the curriculum include K. B. Cady, D. A. Hammer, R. W. Kay, and K. Ünlü

Undergraduate Study

Although there is no special undergraduate field program in nuclear science and engineering, students who intend to enter graduate programs in this area are encouraged to begin specialization at the undergraduate level. This may be done by choice of electives within regular field programs (such as those in engineering physics, materials science and engineering, computer science, and civil, chemical, electrical, or mechanical engineering) or within the College Program.

Master of Engineering (Nuclear) Degree Program

The two-term curriculum leading to the M.Eng. (Nuclear) degree is intended primarily for individuals who want a terminal professional degree, but it may also serve as preparation for doctoral study in nuclear science and engineering. The course of study covers the basic principles of nuclear reactor systems with a major emphasis on reactor safety and radiation protection and control. The special facilities of the Ward Center for Nuclear Sciences are described in the *Announcement of the Graduate School*.

The interdisciplinary nature of nuclear engineering allows students to enter from a variety of undergraduate specializations. The recommended background is (1) an accredited baccalaureate degree in engineering, physics, or applied science; (2) physics, including atomic and nuclear physics; (3) mathematics, including advanced calculus; and (4) thermodynamics. Students should see that they fulfill these requirements before beginning the program. In some cases, deficiencies in preparatory work may be made up by informal study during the preceding summer. General admission and degree requirements are described in the college's introductory section.

The following courses, or equivalents, are included in the 30-credit program:

Fall term

NS&E 509, Nuclear Physics for Applications

NS&E 612, Nuclear Reactor Theory

NS&E 633, Nuclear Reactor Engineering

Technical elective

Spring term

NS&E 551, Nuclear Measurements in Research

NS&E 545, Energy Seminar

Technical elective

Engineering design project

Mathematics or physics elective

Engineering electives should be in a subject area relevant to nuclear engineering, such as energy conversion, radiation protection and control, feedback control systems, magnetohydrodynamics, controlled thermonuclear fusion, and environmental engineering. The list below gives typical electives.

A&EP 606/ECE 581, Introduction to Plasma Physics (fall, 4 credits)

A&EP 607/ECE 582, Basic Plasma Physics (spring, 4 credits)

A&EP 661, Microcharacterization (fall, 3 credits)

ECE 457, Silicon Device Fundamentals (fall, 4 credits with lab)

ECE 471/M&AE 478/CHEME 372, Feedback Control Systems (fall, 4 credits)

MS&E 459, Physics of Modern Materials Analysis (spring, 3 credits)

MS&E 603, Analytical Techniques for Materials Science (spring, 4 credits)

NS&E 484/A&EP 484/ECE 484/M&AE 459, Introduction to Controlled Fusion: Principles and Technology (spring, 3 credits)

NS&E 521, Radiation Effects in Materials (fall, 1–3 credits)

OPERATIONS RESEARCH AND INDUSTRIAL ENGINEERING

K. B. Athreya, L. J. Billera, R. G. Bland, M. J. Eisner, E. Friedman, S. Henderson, P. L. Jackson, R. A. Jarrow, W. L. Maxwell, J. A. Muckstadt, N. Prabhu, P. Protter, J. Renegar, S. I. Resnick, R. Roundy, D. Ruppert, G. Samorodnitsky, D. Shmoys, E. Tardos, M. J. Todd, L. E. Trotter, Jr., B. W. Turnbull

Bachelor of Science Curriculum in Operations Research and Engineering

The program is designed to provide a broad education in the techniques and modeling concepts needed to analyze and design complex systems and to provide an introduction to the technical and professional areas with which operations researchers and industrial engineers are concerned. The program prepares students for a wide range of careers including operations research, industrial engineering, entrepreneurship, information technology, operations management, consulting, financial engineering, financial services, and management.

The foundation of the B.S. curriculum is the development of basic skills in calculus, statistics, probability, mathematical programming, and computer science. Required courses in manufacturing systems and simulation build on these skills and provide engineering design experiences. The curriculum culminates in a major engineering design experience in one of two required OR&IE electives, OR&IE 416 or 480.

Because of the wide range of career goals among our students, the B.S. program is designed with a minimum of required courses and a large number of required electives. Students should consult with their field advisers to select electives that best meet their future goals.

The program is accredited as a "nontraditional" program by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET). The faculty have not sought accreditation of the B.S. curriculum as a program in industrial engineering. Industrial engineering curricula, while excellent for preparing industrial engineers, do not have the flexibility that the wide range of our students requires. Nonetheless, by proper selection of field electives, graduates of the B.S. program can and do become highly successful and competent industrial engineers. (Exceptional students interested in pursuing graduate studies are encouraged to speak with their faculty advisers concerning an accelerated program of study.)

A student who intends to enter the field program in Operations Research and Engineering should plan to take Basic Engineering Probability and Statistics (ENGRD 270) after completing MATH 192. Early consultation with a faculty member of the school or with the associate director for undergraduate studies can be helpful in making appropriate choices. The required courses for the OR&E field program and the typical terms in which they are taken are as follows:

Term 2, 3, or 4	*Credits*
ENGRD 211, Computers & Programming	3
Term 5	
OR&IE 320, Optimization I	4
OR&IE 350, Financial and Managerial Accounting	4
OR&IE 360, Engineering Probability and Statistics II	4
Humanities/Social Sciences elective	3
Field-approved elective	3
Term 6	
OR&IE 310, Industrial Systems Analysis 4 (may be taken in term 4)	
OR&IE 321, Optimization II	4
OR&IE 361, Introductory Engineering Stochastic Processes I	4
Behavioral science (organizational behavior)†	3
Humanities/Social Sciences elective	3

†The behavioral science requirement can be satisfied by any one of several courses, including the Johnson Graduate School of Management (JGSM) course, NCC 554 (offered only in the fall), which is recommended for those contemplating the pursuit of a graduate business degree, ILROB 170, 171, and 320, and H ADM 115.

The basic senior-year program, from which individualized programs are developed, consists of the following courses:

	Minimum credits
OR&IE 580, Simulation Modeling and Analysis	4
Either OR&IE 416 or OR&IE 480 (program design requirement)	4
Three upperclass OR&IE electives as described below	9
Two field-approved electives (at least 3 credits must be outside OR&IE)	6
Two Humanities/Social Sciences electives	6
Two approved electives	6

Available OR&IE electives are as follows:

Manufacturing and distribution systems: OR&IE 414, 416, 451, 480, 481, 518, 524, 525, and 562 and JGSM NBA 641

Optimization methods: OR&IE 431, 432, 434, 435, and 436

Applied probability and statistics: OR&IE 462, 474, 476 (2 credits), 561, 563, 575 (2 credits), 576 (2 credits) and 577

Scholastic requirements for the field are: a passing grade in every course; a grade of C- or better in each of ENGRD 211 and 270, OR&IE 310, 320, 321, 350, 360, 361 and 580; an overall average of at least 2.0 for each term the student is enrolled in the school; an average of 2.0 or better for OR&IE field courses; satisfactory progress toward the completion of the degree requirements. The student's performance is reviewed at the conclusion of each term.

Operations Research and Engineering Honors Program

Eligibility

The Bachelor of Science degree with honors will be granted to students who, in addition to having completed the degree requirements, have satisfactorily completed the honors program in Operations Research and Engineering and have been recommended for the degree by the honors committee of the department. An honors program student must enter with and maintain a cumulative GPA of at least 3.5.

Content

An OR&E honors program shall consist of at least nine credits beyond the minimum required for graduation in OR&E, so that no part of the honors program can also be used to satisfy graduation requirements. The nine credits shall be from one or more of the following with at least four hours in the first category:

1. Advanced courses in OR&IE at the 500-level or above.
2. A significant research experience or honors project under the direct supervision of an OR&IE faculty member using OR&IE 499: OR&IE Project. A significant written report must be submitted as part of this component.
3. A significant teaching experience under the direct supervision of a faculty member in OR&IE using OR&IE 490: Teaching in OR&IE, or ENGRG 470: Undergraduate Engineering Teaching.

Timing

All interested students must complete a written application no later than the end of the third week of the first semester of their senior year, but are encouraged to make arrangements with a faculty member during the first semester of their junior year. A student must be in the honors program for at least two semesters before graduation.

Procedures

Each application to the OR&E honors program must have a faculty adviser to supervise the honors program. The honors adviser need not be the student's faculty adviser. The application to the program shall be a letter from the student describing the specific proposed honors program and including the explicit approval of the honors adviser. Each program must be approved by the associate director, and any changes to the student's program must also be approved by the associate director of undergraduate studies.

Engineering Minor Programs

The School of Operations Research and Industrial Engineering currently offers three engineering minor programs: engineering statistics, industrial systems and information technology, and operations research and management science. (A student may not receive credit for more than one minor offered by the School of Operations Research and Industrial Engineering.) Descriptions and requirements for each program follow:

Minor in Engineering Statistics

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the engineering statistics minor: BEE, A&EP, CEE, CHEME, COM S, EAS, ECE, M&AE, MS&E.

This minor requires the student to develop expertise in engineering statistics. The goal of the program is to provide the student with a firm understanding of statistical principles and engineering applications, and the ability to apply this knowledge in real-world situations.

The requirements for the engineering statistics minor are outlined below. For further details consult the Operations Research and Industrial Engineering Undergraduate Programs Office, 202 Rhodes Hall.

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits), chosen as follows:

I. Required Courses:

ENGRD 270 Basic Engineering Probability & Statistics

OR&IE 360 or ECE 310 Basic Engineering Probability & Statistics II or Introduction to Probability & Random Signals

II. Four courses (11 credits minimum) taken from the following list*:

OR&IE 361 or ECE 411 Introductory Engineering Stochastic Processes I or Random Signals in Communications/ Signal Processing

OR&IE 476 Applied Linear Statistical Models

OR&IE 576 Regression

OR&IE 563 Applied Time Series Analysis

OR&IE 565 Applied Financial Engineering

OR&IE 575 Experimental Design

OR&IE 577 Quality Control

OR&IE 580 Simulation Modeling and Analysis

MATH 472 or BTRY 409 Basic Probability or Theory of Statistics

BTRY 602 Statistical Methods II

BTRY 603 or ILRST 411 Statistical Methods III or Statistical Analysis of Qualitative Data

ILRST 310 Statistical Sampling

ILRST 314 Graphical Methods for Data Analysis

ILRST 410 Techniques of Multivariate Analysis

*Other course options approved by petition in advance. The student should be aware that some of these courses require others as prerequisites. All these courses are cross-listed under the Department of Statistical Science.

Academic Standards: a letter grade of C- or better for each course in the minor and a cumulative GPA of 2.0 or better for all courses in the minor.

Minor in Industrial Systems and Information Technology

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the industrial systems and information technology minor: BEE, A&EP, CEE, CHEME, COM S, EAS, ECE, M&AE, MS&E.

The aim of this minor is to provide an in-depth education in the issues involved in the design and analysis of industrial systems, and the tools from information technology that have become an integral part of the manufacturing process. Students will become familiar with the problems, perspectives, and methods of modern industrial engineering and be prepared to work with industrial engineers in designing and managing manufacturing and service operations. That is, rather than providing a comprehensive view of the range of methodological foundations of operations research, this minor is designed to give the student a focused education in the application area most closely associated with these techniques.

The requirements for the industrial systems and information technology minor are outlined below. For further details consult the Operations Research and Industrial Engineering Undergraduate Programs Office, 200 Rhodes Hall.

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits), chosen as follows:

I. At least three of the following:

ENGRD 270 Basic Engineering Probability and Statistics

OR&IE 310 Industrial Systems Analysis

OR&IE 320 Optimization I

OR&IE 480 Information Technology for Operations Research and Industrial Technology

II. The remaining courses/credit hours from the following:

OR&IE 350 Financial and Managerial Accounting

OR&IE 416 Design of Manufacturing Systems

OR&IE 451 Economic Analysis of Engineering Systems

OR&IE 525 Production Planning and Scheduling Theory and Practice

OR&IE 552 Revenue Management

OR&IE 577 Quality Control

OR&IE 580 Simulation Modeling and Analysis

Academic Standards: A letter grade of C- or better for each course in the minor and a cumulative GPA of 2.0 or better for all courses in the minor.

Minor in Operations Research and Management Science

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the operations research and management science minor: BEE, A&EP, CEE, CHEME, COM S, EAS, ECE, M&AE, MS&E.

The field of operations research and management science (OR/MS) aims to provide rational bases for decision making by seeking to understand and model complex situations and to use this understanding to predict system behavior and improve system performance. This minor gives the student the opportunity to obtain a wide exposure to the core methodological tools for OR/MS, including mathematical programming, stochastic and statistical models, and simulation. The intent of this minor is that the student should obtain a broad knowledge of these fundamentals, rather than to train the student in a particular application domain. This way the student can adjust their advanced courses and pursue either methodological or application oriented areas of greatest interest and relevance to the overall educational goals of their program.

The requirements for the operations research and management science minor are outlined below. For further details consult the Operations Research and Industrial Engineering Undergraduate Programs Office, 200 Rhodes Hall.

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits), chosen as follows:

I. Choose three courses from the following list:

ENGRD 270 Basic Engineering Probability and Statistics

OR&IE 320 Optimization I

OR&IE 321 Optimization II

OR&IE 360 Engineering Probability and Statistics II

OR&IE 361 Introduction Engineering Stochastic Processes I

OR&IE 580 Simulation Modeling and Analysis

II. These courses are to be supplemented with additional OR&IE courses at the 300 level or higher, so that entire program includes at least six courses and at least 18 credits. For example, taking the remaining three options on this list would suffice.

Academic Standards: a letter grade of C- or better for each course in the minor and a cumulative GPA of 2.0 or better for all courses in the minor.

Master of Engineering (OR&IE) Degree Program

This two-semester professional degree program stresses applications of operations research and industrial engineering. The centerpiece of the program is a team-based project on a real problem. The course work centers on additional study of analytical techniques, with particular emphasis on engineering applications, especially in the design or improvement of systems in manufacturing, information, finance, and nonprofit organizations.

General admission and degree requirements are described in the introductory "Degree Programs" section. The M.Eng. (OR&IE) program is intended for three groups of students: graduates of the undergraduate field program in OR&E who wish to expand their practical knowledge of the field; Cornell undergraduates in other math-based fields who want to broaden their exposure to OR&IE; and qualified non-Cornellians with strong backgrounds from other programs in the United States and abroad.

To ensure completion of the program in two semesters, the entering student should have completed courses in probability and statistics and in computer science, as well as four semesters of mathematics, through differential equations, linear algebra, and multivariate calculus.

Program requirements include a core of OR&IE courses plus technical electives chosen from a broad array of offerings. The choice of a particular elective sequence plus a specific project course results in completion of one of several options within the program. These include the applied operations research option, the manufacturing option, the financial engineering option, the systems engineering option, the information technology concentration, and the Semester in Manufacturing. These options are offered jointly with various other Cornell departments and schools and they provide the opportunity to interact on projects and in class with specialists in other engineering fields and in business. Many students select the applied operations research option, offered only by OR&IE, which has project teams made up entirely of OR&IE M.Eng. students and which offers the broadest choice of elective courses. Students interested in an option other than the applied operations research option should obtain further information from the following: manufacturing option, Center for Manufacturing Enterprise, 101 Frank H. T. Rhodes Hall, 607–255–7757; financial engineering option and information technology option, 201 Frank H. T. Rhodes Hall, 607–255–9128; Semester in Manufacturing option, 304 Sage Hall, 607–255–4691; systems engineering option, 101 Frank H. T. Rhodes Hall, 607–255–7757. For students lacking an undergraduate degree in Operations Research, the financial engineering option may entail additional prerequisites or more than two semesters.

I. For matriculants with preparation comparable to that provided by the undergraduate Field Program in Operations Research and Engineering:

Fall term	*Credits*
OR&IE 516, Case Studies	1
OR&IE 893, Applied OR&IE Colloquium	1
M.Eng. Project	1
Technical electives	12
Spring term	
OR&IE 894, Applied OR&IE Colloquium	1
M.Eng. Project	minimum of 4
Technical electives	10

II. For matriculants from other fields who minimally fulfill the prerequisite requirements (students who have the equivalent of OR&IE 520, 523, and 560 will take other OR&IE electives in their place):

Fall term	*Credits*
OR&IE 560, Engineering Probability and Statistics II	4
OR&IE 520, Optimization I	4
OR&IE 522, Topics in Linear Optimization	1
OR&IE 516, Case Studies	1
OR&IE 580, Simulation Modeling and Analysis	4
OR&IE 893, Applied OR&IE Colloquium	1
M. Eng. Project	1
Spring term	
OR&IE 523, Introduction to Stochastic Processes I	4
OR&IE 894, Applied OR&IE Colloquium	1
M.Eng. Project	minimum of 4
Technical electives	5

For both of the above pro forma schedules, at least 12 credit hours of the specified electives must be chosen from the list of courses offered by the School of Operations Research and Industrial Engineering. For scheduling reasons, some options may require an additional summer, depending on the student's preparations.

A minimum of 30 credit hours are required to complete this program. Additional program requirements exist and are described in the *Master of Engineering Handbook*, which is available in Room 201, Frank H. T. Rhodes Hall and on the web at www.orie.cornell.edu.

The project requirement can be met in a variety of ways. Common elements in all project experiences include working as part of a group of three to five students on an engineering design problem, meeting with a faculty member on a regular basis, and oral and written presentation of the results obtained. Most projects address problems that actually exist in manufacturing firms, financial firms, and service organizations such as hospitals.

Cooperative Program with the Johnson Graduate School of Management

Undergraduates majoring in operations research and engineering may be interested in a cooperative program at Cornell that leads to both Master of Engineering and Master of Business Administration (M.B.A.) degrees. With appropriate curriculum planning, such a combined B.S./M. Eng./M.B.A. program can be completed in six years at Cornell, with time out for work experience. For undergraduates from other schools, it may be feasible to complete the M. Eng./M.B.A. program in two years, possibly with an intervening summer or time out for work experience if they do not already have it on coming to Cornell. This accelerated program often incorporates the Twelve-Month M.B.A. Program of the Johnson Graduate School of Management (JGSM).

An advantage for OR&E majors is that, as part of their undergraduate and/or M. Eng. curriculum, they study several subjects that are required for the M.B.A. degree. (This is because modern management is concerned with the operation of production and service systems, and much of the analytical methodology required to deal with operating decisions is the same as that used by systems engineers in designing these systems.) This early start on meeting the business-degree requirements permits degrees in two years rather than the usual three years for such a combination.

The details of planning courses for this program should be discussed with the admissions office of the JGSM. Since 95 percent of the students in the JGSM have work experience, there will typically be a gap for work experience between the M. Eng. and M.B.A. portions of the program for students who do not already have it when beginning the M. Eng. portion.

Further details and application forms may be obtained at the office of the School of Operations Research and Industrial Engineering, 201 Frank H. T. Rhodes Hall (or meng@cornell.edu), and at the admissions office of the Johnson Graduate School of Management (mba@johnson.cornell.edu).

The Knight Scholars program, open to Cornell engineering graduates, provides financial support for the M.Eng./M.B.A. combination. Further details are available in 146 Olin Hall, (607) 255–7413.

STATISTICAL SCIENCE DEPARTMENT

The university-wide Department of Statistical Science coordinates undergraduate and graduate study in Statistics and Probability. A list of suitable courses can be found in the Interdisciplinary Centers, Programs, and Studies section at the front of this catalog.

THEORETICAL AND APPLIED MECHANICS

T. J. Healey, chair; J. A. Burns, K. B. Cady, C. Castillo-Chavez, H. D. Conway, (Emeritus) J. M. Guckenheimer, C. Y. Hui, J. T. Jenkins, S. Mukherjee, S. L. Phoenix, R. H. Rand, P. Rosakis, A. L. Ruina, W. H. Sachse, S. Strogatz, Z. J. Wang, A. Zehnder

Undergraduate Study

The Department of Theoretical and Applied Mechanics is responsible for courses in engineering mechanics and engineering mathematics, some of which are part of the Common Curriculum.

College Program in Engineering Science

A student may enroll in the College Program in Engineering Science, which is sponsored by the Department of Theoretical and Applied Mechanics. The College Program is described in the section on undergraduate study in the College of Engineering.

Minor in Applied Mathematics

Eligibility

Engineering undergraduates affiliated with the following fields are eligible to participate in the Applied Mathematics minor: BEE, A&EP, CEE, CHEME, COM S, EAS, ECE, M&AE, MS&E, OR&IE. Contact persons: Richard Rand, 207 Kimball Hall, 255–7145, rhr2@cornell.edu and Tim Healey, 211 Kimball Hall, 255–3738, tjh10@cornell.edu

Requirements

To complete the minor, the student must take at least six (6) courses beyond MATH 294, to be chosen as follows:

a) No more than one (1) course may be chosen from any one of the groups 1, 2, 3, or 4.

b) At least three (3) courses must be chosen from groups 5 and 6.

c) No more than one (1) 200-level course may be chosen.

d) No more than one (1) course may be chosen which is offered by the student's major department.

1. Analysis

   T&AM 310 Advanced Engineering Analysis I

   MATH 311 Introduction to Analysis

   MATH 420 Differential Equations and Dynamical Systems

   A&EP 321 Mathematical Physics I

2. Computational Methods

   COM S/ENGRD 322 Introduction to Scientific Computation

   BEE 449 Computational Tools for Engineers

   CEE/ENGRD 241 Engineering Computation

   OR&IE 320 Optimization I

3. Probability and Statistics

   OR&IE/ENGRD 270 Basic Engineering Probability and Statistics

   OR&IE 360 Engineering Probability and Statistics II

   ECE 310 Introduction to Probability and Random Signals

   CEE 304 Uncertainty Analysis in Engineering

4. Applications

   A&EP 333 Mechanics of Particles and Solid Bodies

   CHEME 323 Fluid Mechanics

   CEE 331 Fluid Mechanics

   CEE 371 Structural Behavior

   ECE 425 Digital Signal Processing

   MS&E 303 Thermodynamics of Condensed Systems

   M&AE 323 Introductory Fluid Mechanics

5. Advanced Courses

   —Only one of the following three may be chosen:

   T&AM 311 Advanced Engineering Analysis II

   MATH 422 Applied Complex Analysis

   A&EP 322 Mathematical Physics II

   —Only one of the following two may be chosen:

   ECE 411 Random Signals in Communications and Signal Processing

   OR&IE 361 Introductory Engineering Stochastic Processes I

   —Only one of the following two may be chosen:

   COM S 381 Introduction to Theory of Computing

   COM S 481 Introduction to Theory of Computing

   COM S 482 Introduction to the Design of Algorithms

   OR&IE 321 Optimization II

   OR&IE 431 Discrete Models

   OR&IE 435 Introduction to Game Theory

   OR&IE 462 Introductory Engineering Stochastic Processes II

   ECE 522 Nonlinear Systems: Analysis, Stability, Control, and Applications

   —Only one of the following two may be chosen:

   M&AE 571 Applied Dynamics

   T&AM 570 Intermediate Dynamics

   T&AM 578 Nonlinear Dynamics and Chaos

6. Math Courses—Any 300+ level course offered by the Mathematics Department in algebra, analysis, probability/statistics, geometry, or logic, with the following exceptions:

   1) MATH 311 or MATH 420, if any course from group 1 is chosen

   2) MATH 422, if T&AM 311, or A&EP 322 are chosen from group 5

Academic Standards: A letter grade of C or better for each course in the minor.

Minor in Biomedical Engineering

Currently undergoing revision. Contact Engineering Advising or Professor Michael Shuler, Director of Bioengineering Program.

Eligibility

All undergraduates in the College of Engineering are eligible to participate in the biomedical engineering minor, unless they are also pursuing the bioengineering option. (Students may participate in either the Bioengineering Option OR the Biomedical Engineering minor, but not both.)

Requirements

To complete the minor, the student must take at least six courses (minimum of 18 credits) from the five groups listed below, with at least one course from each group. At least four of the six courses must be from outside the student's major. In addition to the six courses for a minimum of 18 credits, all students must take ENGRG 501, Bioengineering Seminar (1 credit).

Required Course: ENGRG 501, Bioengineering Seminar (1 credit)

I. Biomaterials and Biomechanics

BEE 365 (3) Properties of Biological Materials

MS&E 265 (3) or TXA 439 (2) Biological Materials and Their Synthetic Replacements

MS&E 463 (3) Neuromuscular Biomechanics

M&AE 464 (3) Orthopaedic Tissue Mechanics

M&AE 565 (3) Biomechanical Systems—Analysis and Design

M&AE 663 (3) Advanced Topics in Neuromuscular Biomechanics

M&AE 664 (3) Mechanics of Bone

ENGRG 605.3 (1) Biomaterials

ENGRG 606.1 (1) Artificial Organs and Tissue Engineering

ENGRG 606.3 (1) Biomechanics of Musculoskeletal Systems

II. Biomedical Systems

BEE 453 (3) Computer-Aided Engineering: Applications to Biomedical and Food Processes

CHEME 481 (3) Biomedical Engineering

BEE 454 (3) Physiological Engineering

ENGRG 605.1 (1) Cellular Dynamics and Cancer

ENGRG 605.2 (1) Physiological Systems

CHEME 401 (3) Molecular Principles of Biomedical Engineering

III. Instrumentation

BEE 450 (4) Bioinstrumentation

BEE 458 (4) Introduction to Biotechnology

ECE 432 (3) MicroElectro Mechanical Systems (MEMS)

ECE 511 (3) Bioelectric Signal Analysis and Processing

ENGRG 606.2 (1) Biomedical Instrumentation and Diagnosis

BEE 659/BEE 459 (4) Biosensors and Bioanalytical Techniques

IV. Molecular and Cell Biology

BIOGD 281 (5) Genetics

BIOGD 282 (2–3) Human Genetics

BIOMI 290 (3) Microbiology

BIOAP 316 (4) Cellular Physiology

BIOBM 330–333 (2–4) Principles of Biochemistry

BIOBM 432 (3) Survey of Cell Biology

V. Physiology

BIOAP 212 (3) Human Physiology

BIOAP 311 (3) Introductory Animal Physiology

BIOAP 313 (4) Histology: The Biology of the Tissues

BIOGD 389 (3) Embryology

BIONB 222 (3–4) Neurobiology and Behavior II: Introduction to Neurobiology

AN SC 427 (3) Fundamentals of Endocrinology

M&AE 463 (3) Neuromuscular Biomechanics

Academic Standards: A letter grade of C- or better for each course in the minor and a cumulative GPA of 2.0 or better for all courses in the minor.

Note: ENGRG 605–606 and M&AE 664 are graduate courses with limited enrollment. First preference will be given to graduate students.

Master of Engineering (Engineering Mechanics) Degree Program

This program emphasizes fundamentals in engineering science and applied mathematics. In this way the student is prepared to handle a wide variety of multi-disciplinary problems. The program is designed for engineering students and students from the physical and mathematical sciences.

The degree program requires satisfactory completion of 30 credits of coursework, including 12 credits that involve analysis, computation, design, or laboratory experience. Of these 12 credits, at least 6 must be earned in Theoretical & Applied Mechanics (T&AM). Up to 10 credits will be awarded for an M. Eng. project. The balance of the required 30 credits can be obtained as electives from T&AM or from other departments in the engineering, physical or mathematical sciences. As a consequence, the student has great flexibility in choosing a course of study tailored to his or her interests.

Projects may be chosen from the current interests of the faculty, including: nonlinear dynamics and chaos (with applications to problems in physics, engineering and biology), solid mechanics (fracture mechanics, nonlinear elasticity, shape-memory alloys, composite materials, ultrasonics and acoustics), fluid mechanics (granular materials), space mechanics (evolution of the solar system, planetary rings).

The Department of Theoretical and Applied Mechanics has several laboratories equipped for the fabrication and mechanical testing of composite materials and structures. Extensive computing resources are available for numerical computations, design, or other numerical- or simulation-research activities related to composites. The Materials Science Center, the Center for Theory and Simulation in Science and Engineering, and the Computer-Aided Design Instructional Facility provide additional state-of-the-art laboratories and computer resources.

ENGINEERING COURSES

Courses offered in the College of Engineering are listed under the various departments and schools.

Courses are identified with a standard abbreviation followed by a three-digit number.

Engineering Communications	ENGRC
Engineering Distribution	ENGRD
Engineering General Interest	ENGRG
Introduction to Engineering	ENGRI
Biological and Environmental Engineering	BEE
Applied and Engineering Physics	A&EP
Chemical Engineering	CHEME
Civil and Environmental Engineering	CEE
Computer Science	COM S
Earth and Atmospheric Sciences (formerly Geological Sciences)	EAS
Electrical and Computer Engineering	ECE
Materials Science and Engineering	MS&E
Mechanical and Aerospace Engineering	M&AE
Nuclear Science and Engineering	NS&E
Operations Research and Industrial Engineering	OR&IE
Theoretical and Applied Mechanics	T&AM

ENGINEERING COMMON COURSES

Engineering Communications Courses

Courses in this category, offered by the Engineering Communications Program, develop writing and oral-presentation skills needed by engineers.

ENGRC 301 Writing in Engineering

TBA. 1 credit. Prerequisite: permission of instructor. Can be used to satisfy requirements in expressive arts as a free or approved elective.

Some "writing-intensive" engineering classes may require students to enroll in this supplementary course. Instructors from the Engineering Communications Program work with engineering faculty members to prepare students for writing assignments. Intended to strengthen understanding of the course content while enhancing communications skills. May be taken more than once, with different engineering courses. This course may be taken *only* in conjunction with, and when required for, particular "writing-intensive" engineering classes.

ENGRC 334 Independent Study in Engineering Communications

TBA. Variable credits (1–3).

Students work closely with a Communications Program instructor to pursue an aspect of professional communications in more depth than is possible in the ECP's regular courses. Possible projects: technical documentation, creating user manuals, analyzing and producing technical graphics, reading and writing about problems in engineering practice, and others. Interested students should contact the Engineering Communications Program, 465 Hollister Hall.

ENGRC 335 Communications For Engineering Managers

TBA. 3 credits. Limited to 20 students per section. Prerequisite: two first-year writing seminars.

This seminar focuses on communications in organizational contexts common to engineering graduates. Topics include internal and external communications; balancing visual and verbal elements in documents and presentations; teamwork and leadership; running and attending meetings; management strategies; and communicating with colleagues, superiors, subordinates, and clients. Students develop writing and management strategies that they apply in individual and collaborative assignments. They learn how to organize technical and managerial information, articulate and support ideas, and address technical and nontechnical audiences. Fulfills the college's technical-writing requirement.

ENGRC 350 Engineering Communications

Fall, spring, summer TBA. 3 credits. Prerequisite: two first-year writing seminars. Limited to 20 students per section.

The ability to communicate well is a factor in being hired, as well as being promoted; the higher an engineer rises, the more writing and presentation he/she does. Engineers write various types of documents, give oral presentations, and design visuals for both. ENGRC 350 helps students learn how to accomplish these important tasks. It draws on material from professional contexts, particularly engineering settings. Students learn how to communicate specialized information to different audiences (e.g., technical and non-technical, colleagues and clients, peers and supervisors), work in teams, and address organizational and ethical issues. Diverse assignments of different lengths. Course material generates lively discussion, and the limited class size ensures close attention to each student's work. Fulfills the college's technical-writing requirement.

Engineering Distribution Courses

Courses in this category are sophomore-level courses cross-listed with a department. These courses are intended to introduce students to more advanced concepts of engineering and may require pre- or corequisites.

ENGRD 201 Introduction to the Physics and Chemistry of the Earth (also EAS 201)

Fall. 3 credits. Prerequisites: PHYS 112 or 207. L. M. Cathles.

This course covers the formation of the solar system: accretion and evolution of the earth; the rock cycle: radioactive isotopes and the geological time scale, plate tectonics, rock and minerals, earth dynamics, mantle plumes; the hydrologic cycle: runoff, floods and sedimentation, groundwater flow, contaminant transport; and the weathering cycle: chemical cycles, CO_2 (weathering), rock cycle, controls on global temperature (CO_2 or ocean currents), oil and mineral resources.

ENGRD 202 Mechanics of Solids (also T&AM 202)

Fall, spring. 3 credits. Prerequisite: PHYS 112, coregistration in MATH 293 or permission of instructor.

Covers: principles of statics, force systems, and equilibrium; frameworks; mechanics of deformable solids, stress, strain, statically indeterminate problems; mechanical properties of engineering materials; axial force, shearing force, bending moment, plane stress; Mohr's circle; bending and torsion of bars; and buckling and plastic behavior.

ENGRD 203 Dynamics (also T&AM 203)

Fall, spring. 3 credits. Prerequisite: T&AM 202, coregistration in MATH 294, or permission of instructor.

Newtonian dynamics of a particle, systems of particles, a rigid body. Kinematics, motion relative to a moving frame. Impulse, momentum, angular momentum, energy. Rigid-body kinematics, angular velocity, moment of momentum, the inertia tensor. Euler equations, the gyroscope.

ENGRD 210 Introduction To Circuits For Electrical and Computer Engineers (also ECE 210)

Fall, spring. 3 or 4 credits. Corequisites: MATH 293 and PHYS 213. ECE majors must take 4 credits, includes the lab. Non-ECE majors can take 3 credits, lecture only, without the lab. Fall, J. C. Belina, C. E. Seyler; spring, M. C. Kelley, P. M. Kintner.

This is a first course in electrical circuits and electronics that establishes the fundamental properties of circuits with application to modern electronics. Topics include circuit analysis methods, operational amplifiers, basic filter circuits, and elementary transistor principles. The laboratory experiments are closely coupled with the lectures and there is a final design project.

COM S 211 Computers and Programming (also ENGRD 211)

Fall, spring, summer. 3 credits. Prerequisite: COM S 100 or an equivalent course in Java or C++.

Intermediate programming in a high-level language and introduction to computer science. Topics include program structure and organization, object-oriented programming (classes, objects, types, sub-typing), graphical user interfaces, algorithm analysis (asymptotic complexity, big "O" notation), recursion, data structures (lists, trees, stacks, queues, heaps, search trees, hash tables, graphs), simple graph algorithms. Java is the principal programming language.

ENGRD 219 Mass and Energy Balances (also CHEME 219)

Fall. 3 credits. Corequisite: physical chemistry or permission of instructor. K. H. Lee.

Engineering problems involving material and energy balances. Batch and continuous reactive systems in the steady and unsteady states. Introduction to phase equilibria for multicomponent systems.

ENGRD 221 Thermodynamics (also M&AE 221)

Fall, spring, summer TBA. 3 credits. Prerequisites: MATH 192 and PHYS 112.

The definitions, concepts, and laws of thermodynamics. Applications to ideal and real gases, vapor and gas power systems, refrigeration, and heat pump systems. Thermodynamic relations for simple, compressible substances. Combustion and chemical equalibrium. Examples and problems are related to contemporary aspects of power generation and broader environmental issues.

ENGRD 230 Introduction to Digital Logic Design

Fall, spring. 4 credits. Prerequisite: COM S 100. W. E. Speight.

Introduction to the design and implementation of practical digital circuits. Topics include transistor network design, Boolean algebra, combinational circuits, sequential circuits, finite state machine design, and analog and digital converters. Design methodology using both discrete components and hardware description languages is covered in the weekly laboratory portion of the course.

ENGRD 241 Engineering Computation (also CEE 241)

Fall, spring. 3 credits. Prerequisites: COM S 100 and MATH 293. Corequisite: MATH 294. (Completion of MATH 294 is suggested.) J. F. Abel, W. D. Philpot.

Introduction to numerical methods, numerical mathematics, and probability and statistics. Development of programming and graphics proficiency with MATLAB and spreadsheets. Numerical analysis topics considered are: accuracy, precision, Taylor-series approximations, truncation and round-off errors, condition numbers, operation counts, convergence, and stability. Included are numerical methods for solving engineering problems that entail roots of functions, simultaneous linear equations, regression, curve fitting, interpolation, numerical differentiation and integration, and ordinary and partial differential equations. Introduction to finite difference and finite element methods. Applications are drawn from different areas of engineering.

ENGRD 250 Engineering Applications in Biological Systems (also BEE 250)

Fall. 3 credits. Corequisite: MATH 293. Recommended for the sophomore year. B. A. Ahner.

Case studies of engineering problems in agricultural, biological, and environmental systems, including bioremediation, crop production, environmental controls, energy, biomedicine, and food engineering. Emphasis is on the application of mathematics, physics, and the engineering sciences to energy and mass balances in biological systems.

ENGRD 261 Mechanical Properties of Materials: From Nanodevices to Superstructures

Fall. 3 credits. S. P. Baker.

The mechanical properties of materials (strength, stiffness, toughness, ductility, and so on) and their physical origins are examined. The relationship of the elastic, plastic, and fracture behavior to microscopic structure in metals, ceramics, polymers, and composite materials is explored. Effects of time and temperature on materials properties are discussed. The emphasis of this course is on considerations for design and optimum performance of materials and engineered objects.

ENGRD 262 Electronic Materials for the Information Age (also MS&E 262)

Fall. 3 credits. Prerequisite: MATH 192; corequisite PHYS 213 or permission of instructor. G. Malliaras.

The course examines the electrical and optical properties of materials. Topics covered include the mechanism of electrical conduction in metals, semiconductors and insulators, the tuning of electrical properties in semiconductors, the transport of charge across metal/semiconductor and semiconductor/semiconductor junctions, and the interaction of materials with light. Applications in electrophotography, solar cells, electronics, and display technologies are discussed.

ENGRD 264 Computer-Instrumentation Design (also A&EP 264)
Fall, spring. 3 credits. Prerequisites: COM S 100. 1 lec, 1 lab.
This course covers the use of a small computer in an engineering or scientific research laboratory. Various experiments are performed using a PC (Pentium III, 450 MHZ CPU) running Windows 98. The experiments and devices to be investigated include: input and output ports, analog to digital converters (ADC), digital to analog converters (DAC), thermistors, optical sensors, digital temperature control, nonlinear least squares curve fitting of experimental data, thermal diffusion, and viscosity of fluids. A second goal of this course is to develop effective written communication skills in the context of science and engineering. A number of rhetorical principles are presented that can produce clarity in communication without oversimplifying scientific issues. Students prepare progress reports, technical reports, and formal articles based on the experiments.

ENGRD 270 Basic Engineering Probability and Statistics
Fall, spring, summer. 3 credits. Pre- or corequisite: MATH 293. D. Dalthorp.
This course gives students a working knowledge of basic probability and statistics and their application to engineering. Computer analysis of data and simulation are included. Topics include random variables, probability distributions, expectation, estimation, testing, experimental design, quality control, and regression.

ENGRD 321 Numerical Methods in Computational Molecular Biology (also BIOBM 321 and COM S 321)
Fall. 3 credits. Prerequisites: at least one course in calculus such as MATH 106, 111, or 191 and a course in linear algebra such as MATH 221 or 294 or BTRY 417. COM S 100 or equivalent and some familiarity with iteration, arrays, and procedures. Staff.
An introduction to numerical computing using Matlab organized around five applications: the analysis of protein shapes, dynamics, protein folding, score functions, and field equations. Students become adept at plotting, linear equation solving, least squares fitting, and cubic spline interpolation. More advanced problem-solving techniques that involve eigenvalue analysis, the solution of ordinary and partial differential equations, linear programming, and nonlinear minimization are also treated. The goal of the course is to develop a practical computational expertise with Matlab and to build mathematical intuition for the problems of molecular biology. COMA majors may use only one of the following towards their degree: COM S 321, 322, or 421.

ENGRD 322 Introduction to Scientific Computation (also COM S 322)
Spring, summer. 3 credits. Prerequisites: COM S 100 and (MATH 222 or 294).
An introduction to elementary numerical analysis and scientific computation. Topics include interpolation, quadrature, linear and nonlinear equation solving, least-squares fitting, and ordinary differential equations. The MATLAB computing environment is used. Vectorization, efficiency, reliability, and stability are stressed. Special lectures cover parallel computation.

Courses of General Interest

Courses in this category are of general interest and cover technical, historical, and social issues relevant to the engineering profession. These courses may also include seminar or tutorial type courses.

ENGRG 102 Drawing and Engineering Design (also M&AE 102)
Fall, spring. 1 credit. S-U grades only. Four week course. Offered three times in fall and at least one time in spring. Introducing computer-aided design and basic techniques of mechanical drawing. For students intending to affiliate with M&AE, this course must be completed by the third term, or by the fourth week of M&AE 225.

ENGRG 150 Engineering Seminar
Fall. 1 credit. First-year students only. S-U grades only.
Engineering freshmen meet weekly with their faculty advisers to discuss a range of engineering topics. Discussions may include the engineering curriculum and student programs, what different types of engineers do, the character of engineering careers, active research areas in the college and in engineering in general, and study and examination skills useful for engineering students. Groups may visit campus academic, engineering, and research facilities.

ENGRG 198 Introduction to the Electronic Revolution (also ECE 198)
Summer only. 3 credits. Cannot be taken in addition to ENGRG 298.
This course is an introductory survey of the development of information technologies in the United States from the 1830s to the present. Students focus on the themes of the social process of invention, the federal government's role in promoting and regulating technological change, and the relationship between technological and social change in regard to the history of the telegraph, telephone, radio, television, computers, and the Internet. The themes of gender and technology and the relationship between science and technology are addressed throughout the course. Laboratory demonstrations of current research in information technology at Cornell are given in some afternoon sessions.

ENGRG 250 Technology in Society (also ECE 250, HIST 250, S&TS 250)
Fall. 3 credits. A humanities elective for engineering students. R. R. Kline.
This course investigates the history of technology in Europe and the United States from ancient times to the present. Topics include the economic and social aspects of industrialization; the myths of heroic inventors like Morse, Edison, and Ford; the government's regulation of technology, the origins of mass production; and the spread of the automobile and microelectronics cultures in the United States.

ENGRG 298 Inventing an Information Society (also ECE 298, S&TS 292, and HIST 292)
Spring. 3 credits. Approved for humanities distribution. Cannot be taken for credit after ENGRG 198/ECE 198. R. R. Kline.
Explores the history of information technology from the 1830s to the present by considering the technical and social history of telecommunications, the electric-power industry, radio, television, computers, and the Internet. Emphasis is placed on the changing relationship between science and technology, the economic aspects of innovation, gender and technology, and other social relations of this technology.

ENGRG 323 Engineering Economics and Management (also CEE 323)
Spring, usually offered in summer for Engineering Co-op Program. 3 credits. Primarily for juniors and seniors. Student must register under CEE 323. D. P. Loucks.
Introduction to engineering and business economics and to project management. Intended to give students a working knowledge of money management and how to make economic comparisons of alternative engineering designs or projects. The impact of inflation, taxation, depreciation, financial planning, economic optimization, project scheduling, and legal and regulatory issues are introduced and applied to economic investment and project-management problems.

ENGRG 461 Entrepreneurship For Engineers (also M&AE 461, OR&IE 452)
Fall. 3 credits. Enrollment open to upper class engineers; others with permission of instructor.
For description, see M&AE 461.

ENGRG 501 Bioengineering Seminar
Fall, spring. 1 credit. For juniors, seniors, and graduate students only. Staff.
Broad survey of all aspects of bioengineering, including biomedical, bioprocess, biological, and bioenvironmental engineering and aspects of biotechnology. Sessions may be technical presentations or discussions. Sessions may occasionally be held outside of scheduled times.

ENGRG 605 Fundamentals of Biomedical Engineering I (also CHEME 605)
Fall. 1–4 credits (1 credit per section). Prerequisites: graduate standing in Engineering or Science; PHYS 213 and MATH 294 or equivalent. **Undergraduates must have permission of instructor**. S-U grades optional for students not majoring or minoring in biomedical engineering. Coordinator: M. L. Shuler.
A series of four-week modules on specialized topics.

605.1 Cellular Dynamics and Cancer
1 credit. Meets first third of term. D. Luo and staff.
Basic concepts of cell biology. Mathematical models of cell cycle, receptor-mediated signaling, and cell adhesion. Conceptual approaches for engineering solutions to cancer.

605.2 Physiological Systems
1 credit. Meets second third of term. Staff.
Emphasis is on development of physiologically-based pharmacokinetic models for drug delivery and on models of cardiovascular system, particularly blood flow.

605.3 Biomaterials
1 credit. Meets final third of term.
C. C. Chu and staff.

The main objective of the biomaterials module is to provide students with an effective background in a wide range of biomaterials that include polymers, metals/alloys, and ceramics and that are currently used in human body repair. After completion of this module, students have the basic and some in-depth knowledge of what biomaterials are made of, how biomaterials contribute to the saving of human lives, the criteria of materials for biomedical use, biocompatibility, failure modes of biomaterials, the current R&D activities in biomaterials, challenges that biomaterials are facing, and future direction of R&D in biomaterials.

605.4 Biomedical Engineering Project
1 credit. Meets final third of term. Must contact instructor before Friday of the third week of September. M. L. Shuler.

Students work in teams on a design problem of their choice related to development of a biomedical device or procedure. Each team prepares a written report.

ENGRG 606 Fundamentals of Biomedical Engineering II (also CHEME 606)
Spring. 1–4 credits. Prerequisites: graduate standing in engineering or science; PHYS 213 and MATH 294 or equivalent. **Undergraduates must have permission of instructor**. S-U grades optional for students not majoring or minoring in biomedical engineering. Coordinator: M. L. Shuler.

A series of one and two-credit modules on specialized topics.

606.1 Biomedical Instrumentation and Diagnosis
1 credit. Lec. Meets first third of the term. Staff.

This course gives a perspective on the use of advanced instrumentation for the diagnosis and treatment of disease and the investigation of fundamental biological processes. The basic theory and application of different microscopic and spectroscopic methods, imaging tomographies, and micro-electromechanical devices to biological systems are explored.

606.2 Artificial Organs and Tissue Engineering
1 credit. Prerequisite: ENGRG 605, Section 03 (Biomaterials). Meets second third of term. Staff.

An introduction to the use of cells, biological molecules, and synthetic materials as the basis for building artificial organs and encouraging tissue regeneration. The section discusses the physiological and engineering issues underlying the use of synthetic, extracorporeal systems (e.g., membrane-based dialysis devices), composite implantable materials (e.g., drug-delivery systems and nerve regeneration guides), and hybrid cell/polymer implantable systems (e.g., engineered tissues).

606.3 Biomechanics of Musculoskeletal Systems
2 credits. Meets final third of term.
D. L. Bartel, C. E. Farnum.

Integrated lecture/laboratory experience. The anatomy and function of the canine hindlimb are explored in dissection laboratories and through demonstration of a non-invasive technique, computed tomography. Methods of approximating functional joint loads are discussed, and physical testing is demonstrated. A computer model of the stifle (knee) joint is created by combining knowledge of the anatomy and the mechanical environment.

Introduction to Engineering Courses

Courses in this category are freshman-level courses intended to introduce students to various aspects of engineering. They have no prerequisites and are always cross-listed with a department.

ENGRI 110 The Laser and Its Applications in Science, Technology, and Medicine (also A&EP 110)
Fall, spring. 3 credits.

The principles of laser action, types of laser systems, elements of laser design, and applications of lasers in science, technology, and medicine are discussed. In the laboratory students build and operate a nitrogen laser and a tunable dye laser. Demonstration experiments with several types of lasers illustrate phenomena such as holography, laser processing of materials, and Raman spectroscopy.

ENGRI 111 Nanotechnology
Fall. 3 credits. E. Giannelis.

Nanotechnology has been enabling the Information Revolution with the development of even-faster and more powerful devices for manipulation, storing, and transmitting information. In this hands-on course students learn how to design and manipulate materials to build devices and structures in applications ranging from computers to telecommunications to biotechnology.

ENGRI 112 Introduction to Chemical Engineering (also CHEME 112)
Fall. 3 credits. Limited to freshmen.
T. M. Duncan.

Covers design and analysis of processes involving chemical change. Students learn strategies for design, such as creative thinking, conceptual blockbusting, and (re)definition of the design goal, in the context of contemporary chemical engineering. Includes methods for analyzing designs, such as mathematical modeling, empirical analysis by graphics, and dynamic scaling through dimensional analysis, to assess product quality, economics, safety, and environmental issues.

ENGRI 113 Solving Environmental Problems for Urban Regions (also CEE 113)
Fall. 3 credits. Not open (without instructor's permission) to upper-division engineering students. M. L. Weber-Shirk.

Learn how to design: reservoirs to provide water during droughts, aqueducts to transport water, water treatment plants to prevent waterborne diseases, and landfills to minimize contamination of the environment. Take field trips, build a miniature water treatment plant, and explore new technologies for making safe drinking water.

ENGRI 115 Engineering Applications of Operations Research
Fall, spring. 3 credits. Enrollment not open to OR&E upper-class majors.

An introduction to the problems and methods of Operations Research and Industrial Engineering focusing on problem areas (including inventory, network design, and resource allocation), the situations in which these problems arise, and several standard solution techniques. In the computational laboratory, students encounter problem simulations and use some standard commercial software packages.

ENGRI 116 Modern Structural Systems and Materials (also CEE 116)
Fall. 3 credits. R. Davidson.

An introduction to the process of design, starting with assessing needs, defining performance, and evaluating materials. Discussions and exercises demonstrate how loads are carried not only through large structures, but also how those loads are carried through the micro-structure inside engineering materials. Students are introduced to the physics of structural behavior in bridges, dams, amusement park rides, Broadway and Las Vegas stage sets, and orbital structures. Here on earth students examine how loads like wind and gravity get from the structure to the ground, and how loads like earthquakes get from the ground to the structure. Materials range from traditional wood, metal, soil, rock, and concrete, to modern plastics and fiber composites.

ENGRI 117 Introduction to Mechanical Engineering (also M&AE 117)
Fall or spring, to be determined. 3 credits. Two lectures and one lab per week.

An introduction to the wide range of topics of current interest in mechanical engineering.

ENGRI 118 Design Integration: A Portable CD Player (also MS&E 118 and T&AM 118)
Spring. 3 credits. W. Sachse.

This course examines the roles of various engineering disciplines on the design of a portable compact disc (CD) player. Students are introduced to elements of mechanical, electrical, materials, environmental, manufacturing, and computer engineering as related to the CD player. Laboratory sessions and demonstrations are used to illustrate the principles of design.

ENGRI 119 Biomaterials for the Skeletal System (also MS&E 119)
Fall. 3 credits. D. T. Grubb.

Biomaterials are at the intersection of biology and engineering. This course explores natural structural materials in the human body, their properties and microstructure, and their synthetic and semi-synthetic replacements. Bones, joints, teeth, tendons, and ligaments are used as examples, with their metal, plastic, and ceramic replacements. Topics covered include strength, corrosion, toxicity, wear, and bio-compatibility. Case studies of design lead to consideration of regulatory approval requirements and legal liability issues.

[ENGRI 120 Introduction to Biomedical Engineering (also CHEME 120)
Fall. 3 credits. Not offered 2002–2003.

Introduction to the fundamental science and engineering that spawned the biotechnology revolution—technologies of cell cultures, DNA, and antibodies—and the relationship between biomedical science, bioengineering, and the growing biomedical product industry. Case studies of the development of biotechnical processes, from discovery to clinical use, include processes for vaccines, antibiotics, cancer chemotherapy, protein pharmaceuticals, and organ transplantation.]

ENGRI 121 Fission, Fusion, and Radiation (also A&EP 121 and NS&E 121)
Spring. 3 credits. S-U grades optional for students outside the College of Engineering. K. B. Cady.

Lecture-laboratory course on the physical nature and biological effects of nuclear radiation; benefits and hazards of nuclear energy; light-water reactors, breeder reactors, and fusion reactors; and uses of nuclear radiation in research. Laboratory demonstrations involve Cornell's research reactor; detection of nuclear radiation; activation analysis using gamma-ray spectroscopy; neutron radiography; and pulsed power generators for fusion research.

ENGRI 122 Earthquake! (also EAS 122)
Spring. 3 credits. L. D. Brown.
The science of natural hazards and strategic resources is explored. This course covers techniques for locating and characterizing earthquakes, and assessing the damage they cause; methods of using sound waves to image the earth's interior to search for strategic materials; and the historical importance of such resources. Includes seismic experiments on campus to probe for groundwater, the new critical environmental resource.

ENGRI 124 Designing Materials for the Computer (also MS&E 124)
Spring. 3 credits. 3 lectures.
Introduces the materials, processes and properties of the semiconductors, polymers, ceramics, and metals used in the microelectronics industry to form integrated circuits, electronic devices, and displays. This course examines lithographic processing, metallization, diffusion, ion implantation, oxidation, and other processes used in fabricating electronic devices and their packages. The technology of displays is discussed including liquid crystal displays and light emitting devices.

ENGRI 126 Introduction to Telecommunications
Fall. 3 credits. S. B. Wicker, staff.
This course introduces the technologies that underlie wired and wireless telecommunication systems. The course begins with an introduction to telephony and the public switched telephone network. Modems and cellular telephony are then introduced, along with ISDN and BISDN. The course concludes with an introduction to ATM and TCP/IP. The course includes both lectures and laboratory demonstrations. Students have the opportunity to design communication systems, and to determine their performance through simulations.

ENGRI 127 Introduction to Entrepreneurship and Enterprise Engineering (also M&AE 127)
Spring. 3 credits. Open to all Cornell students regardless of major. No prerequisites.
This course provides a solid introduction to the entrepreneurial process to students in engineering. The main objective is to identify and to begin to develop skills in the engineering work that occurs in high-growth, high-tech ventures. Basic engineering management issues, including the entrepreneurial perspective, opportunity recognition and evaluation, and gathering and managing resources are covered. Technical topics such as the engineering design process, product realization, and technology forecasting are discussed. This course is considered an "Introduction to Engineering" course by the College of Engineering, and satisfies the curricular requirements for such a course. The course is intended for freshmen and is taught from this perspective and at that level.

ENGRI 172 Computation, Information, and Intelligence (also COM S 172)
Fall. 3 credits. Prerequisites: some knowledge of calculus.
An introduction to computer science using methods and examples from the field of artificial intelligence. Topics include game playing, search techniques, learning theory, compute-intensive methods, data mining, information retrieval, the web, natural language processing, machine translation, and the Turing test. This is not a programming course; rather, "pencil and paper" problem sets are assigned. Not open to students who have completed the equivalent of COM S 100.

ENGRI 185 Art, Archaeology, and Analysis (also ARKEO 285, ART 372, ARTH 200, EAS 200, and PHYS 200)
Spring. 3 credits. R. Kay.
An interdepartmental course on the use of techniques of science and engineering in cultural research. Includes applications of physical and physiological principles to the study of archaeological artifacts and works of art. Also covers historical and technical aspects of artistic creation. Students learn analyses by modern methods to deduce geographical origins, and for exploration, dating, and authentication of cultural objects. Does not meet liberal studies distribution requirement for Engineering.

APPLIED AND ENGINEERING PHYSICS

A&EP 110 The Laser and Its Applications in Science, Technology, and Medicine (also ENGRI 110)
Spring. 3 credits.
This is a course in the Introduction to Engineering series. For description, see ENGRI 110.

A&EP 121 Fission, Fusion, and Radiation (also ENGRI 121 and NS&E 121)
Spring. 3 credits. S-U grades optional for students outside the College of Engineering. K. B. Cady.
This is a course in the Introduction to Engineering series. For description, see ENGRI 121.

A&EP 252 The Physics of Life (also ENGRD 252)
Fall. Prerequisites: MATH 192, CHEM 207 or 211, and co-registration in or completion of PHYS 213.
This course introduces the physics of biological macromolecules (e.g. proteins, DNA, RNA) to students of the physical sciences or engineering who have little or no background in biology. The macromolecules are studied from three perspectives. First, the biological role or function of each class of macromolecules is considered. Second, a quantitative description of the physical interactions that determine the behavior of these systems is provided. Finally, techniques that are commonly used to probe these systems, with an emphasis on current research, are discussed.

A&EP 264 Computer-Instrumentation Design (also ENGRD 264)
Fall, spring. 3 credits. Prerequisites: COM S 100. 1 lec, 1 lab.
For description, see ENGRD 264.

A&EP 321 Mathematical Physics I
Fall, summer. 4 credits. Prerequisite: MATH 294. Intended for upper-level undergraduates in the physical sciences.
Review of vector analysis; complex variable theory, Cauchy-Rieman conditions, complex Taylor and Laurent series, Cauchy integral formula and residue techniques, conformal mapping; Fourier Series; Fourier and Laplace transforms; ordinary differential equations; separation of variables. Texts: *Mathematical Methods for Physicists*, by Arfken; *Mathematical Physics*, by Butkov.

A&EP 322 Mathematical Physics II
Spring. 4 credits. Prerequisite: A&EP 321. Second of the 2-course sequence in mathematical physics intended for upper-level undergraduates in the physical sciences.
Topics: partial differential equations, Bessel functions, spherical harmonics, separation of variables, wave and diffusion equations, Laplace, Helmholtz, and Poisson's Equations, transform techniques, Green's functions; integral equations, Fredholm equations, kernals; complex variables, theory, branch points and cuts, Riemann sheets, method of steepest descent; tensors, contravariant, and covariant representations; group theory, matrix representations, class and character. Texts: *Mathematical Methods for Physicists*, by Arfken; *Mathematical Physics*, by Butkov.

Maple Supplement to Mathematical Physics 321 and 322
The course gives a broad based introduction to Maple in applications to problems of mathematical physics similar to those covered in A&EP 321 and 322. We use Maple to solve differential equations—both linear and nonlinear. We make extensive use of plotting capabilities of Maple. Additionally, we cover matrices, complex functions, Laplace and Fourier transforms (and FFTs), and group theory. We also give an introduction to LaTex.

A&EP 330 Modern Experimental Optics (see also PHYS 330)
Fall. 4 credits. Enrollment limited. Prerequisites: PHYS 214 or equivalent. E. Bodenschatz.
A practical laboratory course in basic and modern optics. The various projects cover a wide range of topics from geometrical optics to classical wave properties such as interference, diffraction, and polarization. Each experimental setup is equipped with standard, off-the-shelf optics and opto-mechanical components to provide the students with hands-on experience in practical laboratory techniques currently employed in physics, chemistry, biology, and engineering. Students are also introduced to digital imaging and image processing techniques.

A&EP 333 Mechanics of Particles and Solid Bodies
Fall, summer. 4 credits. Prerequisites: PHYS 112 or 116 and coregistration in A&EP 321 or equivalent or permission of instructor.
This course covers: Newton's mechanics; constants of the motion; many-body systems; linear oscillations; variational calculus; Lagrangian and Hamiltonian formalism for generalized coordinates; non-inertial reference systems; central-force motion; motion of rigid bodies; small vibrations in multi-mass systems; nonlinear oscillations; and basic introduction to relativistic mechanics. Emphasis is on mathematical treatments, physical concepts,

and applications. (On the level of *Classical Dynamics*, by Marion and Thorton).

A&EP 355 Intermediate Electromagnetism

Fall, summer. 4 credits. Prerequisites: PHYS 214 or 217 and coregistration in A&EP 321 or equivalent, or permission of instructor.

Topics: vector calculus, electrostatics, analytic and numerical solutions to Laplace's equation in various geometries, electric and magnetic multipoles, electric and magnetic materials, energy in fields, quasistatics, and magnetic circuit design. Emphasis is on developing proficiency with analyical and numerical solution techniques in order to solve real-world design problems.

A&EP 356 Intermediate Electrodynamics

Spring. 4 credits. Prerequisite: A&EP 355 and coregistration in A&EP 322 or equivalent, or permission of instructor.

Topics: electromagnetic waves, waveguides, transmission lines, dispersive media, radiation, special relativity, interference phenomena. Emphasis is on physical concepts and developing ability to design/analyze micro-wave circuits and antenna arrays.

A&EP 361 Introductory Quantum Mechanics

Spring. 4 credits. Prerequisites: A&EP 333 or PHYS 318; coregistration in A&EP 322 or equivalent and in A&EP 356 or PHYS 326.

A first course in the systematic theory of quantum phenomena. Topics include wave mechanics, the Dirac formalism, angular momentum, the hydrogen atom, and perturbation theory.

A&EP 363 Electronic Circuits (also PHYS 360)

Fall, spring. 4 credits. Prerequisites: PHYS 208 or 213 or permission of the instructor. No previous experience with electronics assumed; however, the course moves quickly through some introductory topics such as basic DC circuits. Fall term usually less crowded. 1 lec, 2 labs. Fall: E. Kirkland; spring: J. Alexander.

Analyze, design, build and experimentally test circuits used in scientific and engineering instrumentation (with discrete components and integrated circuits). Analog circuits: resistors, capacitors, operational amplifiers (linear amplifiers with feedback, oscillators, comparators), filters, diodes and transistors. Digital circuits: combinatorial (gates) and sequential (flip-flops, counters, shift registers) logic. Computer interfacing introduced and used to investigate digital to analog (DAC) and analog to digital conversion (ADC) and signal averaging.

A&EP 403 Introduction to Nuclear Science and Engineering (also ECE 403, M&AE 458, and NS&E 403)

Fall. 3 credits. Prerequisite: PHYS 214 and MATH 294.

For description see NS&E 403.

A&EP 423 Statistical Thermodynamics

Fall. 4 credits. Prerequisite: introductory 3-semester physics sequence plus 1 year of junior-level mathematics.

Quantum statistical basis for equilibrium thermodynamics, microcanonical, canonical and grand canonical ensembles, and partition functions. Classical and quantum ideal gases, paramagnetic and multiple-state systems. Maxwell-Boltzmann, Fermi-Dirac, and Bose-Einstein statistics and applications. Introduction to systems of interacting particles. At the level of *Thermal Physics*, by Kittel and Kroemer, and *Statistical Physics*, by Rosser.

A&EP 434 Continuum Physics

Spring. 4 credits. Prerequisites: A&EP 333 and 356 or equivalent.

Topics: Elasticity and Fluid Mechanics: basic phenomena of elasticity, simple beams, stress and strain tensors, materials equations, equations of motion, general beam equations, waves; fluids: basic phenomena, Navier Stokes equation, scaling laws, Reynolds and Froude numbers, Poisseuille flows, Stokes drag on sphere, boundary layers, invicid and incompressible flows, potential flow, conservation laws, Bernoulli equation, vorticity and circulation, life of wings, jets, instabilities, introduction to turbulence. Projects in combination with AEP 438 possible. At the level of Lai, Rubin and Krempl, *Continuum Mechanics,* and Tritton, *Introduction to Fluid Mechanics*.

A&EP 438 Computational Engineering Physics

Spring. 3 credits. Prerequisites: COM S 100, A&EP 321, 333, 355, 361, or equivalent, or permission of instructor; coregistration in 361 permitted.

Numerical computation (derivatives, integrals, differential equations, matrices, boundary-value problems, relaxation, Monte Carlo methods, etc.) is introduced and applied to engineering physics problems that cannot by solved analytically (three-body problem, electrostatic fields, quantum energy levels, etc.). Computer programming required (in C or optionally C++, FORTRAN, or Pascal). Some prior exposure to programming assumed but no previous experience with C assumed.

A&EP 440 Quantum and Nonlinear Optics

Spring. 4 credits. Prerequisites: A&EP 356, A&EP 361, or equivalent.

An introduction to the fundamentals of the interaction of laser light with matter. Topics include the propagation of laser beams in bulk media and guided-wave structures, the origins of optical nonlinearities, harmonic generation, self-focusing, optical bistability, propagation of ultrashort pulses, solitons, optical phase conjugation, optical resonance and two-level atoms, atom cooling and trapping, multiphoton processes, spontaneous and simulated scattering, and ultra-intense laser-matter interactions.

A&EP 450 Introductory Solid State Physics (also PHYS 454)

Fall. 4 credits. Prerequisites: some exposure to quantum mechanics at the level of PHYS 443, A&EP 361, or CHEM 793 is highly desirable but not absolutely required.

An introduction to the physics of crystalline solids. Covers crystal structures; electronic states; lattice vibrations; and metals, insulators, and semiconductors. Computer simulations of the dynamics of electrons and ions in solids. Optical properties, magnetism, and superconductivity are covered as time allows. The majority of the course addresses the foundations of the subject, but time is devoted to modern and/or technologically important topics such as quantum size effects. At the level of *Introduction to Solid State Physics* by Kittel, or *Solid State Physics* by Ashcroft and Mermun.

A&EP 470 Biophysical Methods (also BIONB 470)

Spring. 3 credits. Prerequisites: solid knowledge of basic physics and mathematics through the sophomore level; some knowledge of cellular biology helpful but not required. Letter grades only.

An overview of the diversity of modern biophysical experimental techniques used in the study of biophysical systems at the cellular and molecular level. Topics covered include methods that examine both structure and function of biological systems, with emphasis on the applications of these methods to biological membranes. The course format includes assigned literature reviews by the students on specific biophysics topics and individual student presentations on these topics. The course is intended for students of the engineering, physics, chemistry, and biological disciplines who seek an introduction to modern biophysical experimental methods.

A&EP 484 Introduction to Controlled Fusion: Principles and Technology (also ECE 484, M&AE 459, and NS&E 484)

Spring. 3 credits. Prerequisites: PHYS 112, 213, and 214, or equivalent background in electricity and magnetism and mechanics; and permission of instructor. Intended for seniors and graduate students. Offered on demand.

For description, see NS&E 484.

A&EP 490 Independent Study in Engineering Physics

Fall, spring. Credit TBA.

Laboratory or theoretical work in any branch of engineering physics under the direction of a member of the faculty. The study can take a number of forms; for example, design of laboratory apparatus, performance of laboratory measurements, computer simulation or software developments, theoretical design and analysis. Details TBA with respective faculty member.

A&EP 550 Applied Solid State Physics

Spring. 3 credits. Prerequisites: A&EP 356, 361, 423, 450 (or equivalent).

Directed at students who have had an introductory course in solid state physics at the level of Kittel. This course concentrates on the application of the quantum mechanical theory of solid state physics to semiconductor materials, solid state electronic devices, solid state detectors and generators of electromagnetic radiation, superconducting devices and materials, the nonlinear optical properties of solids, ferromagnetic materials, nanoscale devices, and mesoscopic quantum mechanical effects. The course stresses the basic, fundamental physics underlying the applications rather than the applications themselves. At the level of *Introduction to Applied Solid State Physics* by Dalven.

A&EP 606 Introduction to Plasma Physics (also ECE 581)

Fall. 4 credits. Prerequisites: ECE 303 or equivalent. First-year graduate-level course; open to exceptional seniors.

For description, see ECE 581.

A&EP 607 Advanced Plasma Physics (also ECE 582)

Spring. 4 credits. Prerequisites: ECE 581 and A&EP 606. Offered on demand.

For description, see ECE 582.

A&EP 633 Nuclear Reactor Engineering (also NS&E 633)
Fall. 4 credits. Prerequisite: introductory course in nuclear engineering. Offered on demand. K. B. Cady.
For description, see NS&E 633.

A&EP 661 Microcharacterization
Fall. 3 credits. Prerequisites: introductory 3-semester physics sequence or an introductory course in modern physics. At the senior/first-year graduate level.
The basic physical principles underlying the many modern microanalytical techniques available for characterizing materials from volumes less than a cubic micron. Discussion centers on the physics of the interaction process by which the characterization is performed, the methodology used in performing the characterization, the advantages and limitations of each technique, and the instrumentation involved in each characterization method.

A&EP 662 Micro/Nano-fabrication and Processing
Spring. 3 credits.
An introduction to the fundamentals of micro and nano-fabricating and patterning thin-film materials and surfaces, with emphasis on electronic and optical materials, micromechanics, and other applications. Vacuum and plasma thin-film deposition processes. Photon, electron, X-ray, and ion-beam lithography. Techniques for pattern replication by plasma and ion processes. Emphasis is on understanding the physics and materials science that define and limit the various processes. At the level of Brodie and Muray.

A&EP 663 Nanobiotechnology (also BIO G 663 and MS&E 563)
Spring. 3 credits. Letter grade only. C. Batt and H. Craighead.
Upper level undergraduate and graduate-level course that covers the basics of biology and the principles and practice of microfabrication techniques. The course focuses on applications in biomedical and biological research. A team design project that stresses interdisciplinary communication and problem solving is one of the course requirements. The course is held twice weekly T R with 75-minute classes. All lectures are teleconferenced to our NBTC associate institutes.

A&EP 711 Principles of Diffraction (also MS&E 671)
Spring. 3 credits. Letter grades only. J. D. Brock.
This course is a graduate-level introduction to diffraction/scattering phenomena in the context of solid-state and soft condensed-matter systems. The primary topic is using the scattering and absorption of neutron, electron, and X-ray beams to study physical systems. Particular emphasis is placed on issues related to synchrotron X-ray sources. Specific topics that are covered in the course include: elastic and inelastic scattering; diffraction from two- and three-dimensional periodic lattices; the Fourier representation of scattering centers and the effects of thermal vibrations and disorder; diffraction, reflectivity, or scattering from surface layers; diffraction or scattering from gases and amorphous materials; small angle scattering; X-ray absorption spectroscopy; resonant (e.g., magnetic) scattering; novel techniques using coherent X-ray beams; and a survey of dynamical diffraction from perfect and imperfect lattices.

A&EP 751 M ENG Project
Fall, spring. 6–12 credits TBA. Required for candidates for the M.Eng. (Engineering Physics) degree.
Independent study under the direction of a member of the university faculty. Students participate in an independent research project through work on a special problem related to their field of interest. A formal and complete research report is required.

A&EP 753 Special Topics Seminar in Applied Physics
Fall. 1 credit. Prerequisite: undergraduate physics. Required for candidates for the M.Eng. (Engineering Physics) degree and recommended for seniors in engineering physics.
Special topics in applied science, with focus on areas of applied physics and engineering that are of current interest. Subjects chosen are researched in the library and presented in a seminar format by the students. Effort is made to integrate the subjects within selected subject areas such as atomic, biological, computational, optical, plasma, and solid-state physics, or microfabrication technology, as suggested by the students and coordinated by the instructor.

BIOLOGICAL AND ENVIRONMENTAL ENGINEERING

For complete course descriptions, see the Biological and Environmental Engineering listing in the College of Agriculture and Life Sciences section or visit the department web site, www.bee.cornell.edu.

BEE 151 Introduction to Computing
Fall. 4 credits. Prerequisite: MATH 191 or equivalent (coregistration permissible). Each lab and recitation section limited to 22 students.

BEE 152 Computer Applications for Engineers
Spring. 3 credits. Prequisites: BEE 151 or equivalent, MATH 191.
Course is comprised of three one-credit modules: (1) MATLAB; (2) spreadsheets; and (3) presentation graphics.

BEE 200 The BEE Experience
Spring. 1 credit.

BEE 250 Engineering Applications in Biological Systems (also ENGRD 250)
Fall. 3 credits. Corequisite: MATH 293. Recommended for the sophomore year.
For description, see ENGRD 250.

BEE 299 Sustainable Development: A Web-Based Course
Spring. 3 credits. Prerequisite: sophomore standing and above. S-U grades optional.

BEE 301 Energy Systems
Spring. 3 credits. Prerequisite: college physics.

BEE 350 Biological and Environmental Transport Processes
Fall. 3 credits. Prerequisites: MATH 294 and fluid mechanics (coregistration permissible).

BEE 365 Properties of Biological Materials
Spring. 3 credits. Prerequisites: ENGRD 202 (coregistration permissible).

BEE 371 Hydrology and the Environment
Spring. 3 credits. Prerequisite: 1 course in calculus.

BEE 411 Biomass Processing: Modelling and Analysis
Spring. 3 credits. Prerequisites: BEE 250, BEE 350 (or any course in heat and mass transport), BIOBM 331, 332, or BIOMI 290.

BEE 425 Science and Technology of Environmental Management
Fall. 3 credits. Open to seniors and graduate students only. Letter grades only.

BEE 427 Water Sampling and Measurement
Fall. 3 credits. Prerequisites: soils and/or fluids or hydrology courses and MATH 191.

BEE 435 Principles of Aquaculture
Spring. 3 credits. Prerequisite: minimum junior standing.

BEE 436 Aquaculture Using Recirculating Water Reuse Technology
Spring. 1 credit. Prerequisite: BEE 435 (co-registration permissable).

BEE 450 Bioinstrumentation
Spring. 4 credits. Prerequisites: linear differential equations, physics or electrical science, computer programming, and use of spreadsheets.

BEE 453 Computer-Aided Engineering: Applications to Biomedical Processes (also M&AE 453)
Spring. 3 credits. Prerequisite: heat and mass transfer (BEE 350 or equivalent).

BEE 454 Physiological Engineering
Fall. 3 credits. Corequisite: fluid mechanics.

BEE 456 Biomechanics of Plants (also BIO PL 456)
Fall. 3 credits. Prerequisites: upper division undergraduate or graduate status, completion of introductory sequence in biology, and 1 year of calculus, or permission of instructor. S-U grades optional.

BEE 458 Introduction to Biotechnology
Fall. 4 credits. Prerequisites: BEE 350 (coregistration permissible), biochemistry, microbiology, fluid mechanics, or permission of instructor.

BEE 459 Biosensors and Bioanalytical Techniques
Spring. 4 credits. Prerequisites: biochemistry or permission of instructor.
For description, see CEE 431.

BEE 471 Geohydrology (also CEE 431 and GEOL/EAS 445)
Fall. 3 credits. Prerequisites: MATH 294 and ENGRD 202.
For description, see CEE 431.

BEE 473 Watershed Engineering
Fall. 3 credits. Prerequisite: fluid mechanics or hydrology.

BEE 474 Drainage and Irrigation Design
Spring. 3 credits. Prerequisites: fluid mechanics or hydrology.

BEE 475 Environmental Systems Analysis
Fall. 3 credits. Prerequisites: MATLAB and 2 years of calculus.

BEE 476 Solid Waste Engineering
Spring. 3 credits. Prerequisites: 1 semester of physics and chemistry.

BEE 478 Ecological Engineering
Spring. 3 credits. Prerequisite: junior-level environmental quality engineering course or equivalent.

BEE 481 LRFD-Based Engineering of Wood Structures (also CEE 481)
Spring. 3 credits. Prerequisite: ENGRD 202.

BEE 489 Engineering Entrepreneurship, Management and Ethics
Spring. 3 credits. Prerequisites: ENGRD 270 or CEE 304 or equivalent, junior standing.

BEE 493 Technical Writing for Engineers
Fall. 1 credit. Prerequisites: BEE 473.

BEE 494 Special Topics in Biological and Environmental Engineering
Fall, spring. 1–4 credits. S-U grades optional.

BEE 495 BEE Honors Research
Fall, spring. 1–6 credits. Prerequisites: enrollment in the BEE Honors Research Program.

BEE 496 Capstone Design in Biological and Environmental Engineering
Fall, spring. 1–3 credits. Prerequisite: senior standing in engineering program or permission of instructor. Completed independent study form (available in 140 Roberts Hall) is required to register.

BEE 497 Individual Study in Biological and Environmental Engineering
Fall, spring. 1–4 credits. Prerequisite: written permission of instructor and adequate ability and training for the work proposed. Normally reserved for seniors in upper two-fifths of their class. S-U grades optional. Completed independent study form (available in 140 Roberts Hall) is required to register.

BEE 498 Undergraduate Teaching
Fall, spring. 1–4 credits. Prerequisite: written permission of instructor. Completed independent study form (available in 140 Roberts Hall) is required to register.

BEE 499 Undergraduate Research
Fall, spring. 1–3 credits. Prerequisites: written permission of instructor; adequate training for work proposed. Normally reserved for seniors in upper two-fifths of their class. Completed independent study form (available in 140 Roberts Hall) is required to register.

BEE 551/552 Agricultural and Biological Engineering Design Project
Fall, 551; spring, 552. 3–6 credits. Prerequisite: admission to the M.Eng. (Agricultural and Biological) degree program.

BEE 651 Bioremediation: Engineering Organisms to Clean Up the Environment
Spring. 3 credits. Prerequisites: BIOMI 290 or BIOMI 398 or BIOMI 331 or permission of instructor.

BEE 652 Instrumentation: Sensors and Transducers
Spring. 3 credits. Prerequisites: linear differential equations, introductory chemistry and introductory physics, or permission of instructor.

BEE 655 Thermodynamics and Its Applications
Spring. 3 credits. Prerequisite: MATH 293 or equivalent.

BEE 658 Biosensors and Bioanalytical Techniques
Spring. 4 credits. Prerequisites: biochemistry and permission of instructor.

BEE 671 Analysis of the Flow of Water and Chemicals in Soils
Fall. 3 credits. Prerequisites: 4 calculus courses and fluid mechanics.

BEE 672 Drainage
Spring. 4 credits. Prerequisites: BEE 471 or BEE 473. S-U grades optional.

BEE 673 Sustainable Development Seminar (also NBA 573)
Spring. 1–3 credits. Prerequisite: upper division undergraduate and graduate students or permission of instructor.

BEE 678 Nonpoint Source Models
Spring. 3 credits. Prerequisites: computer programming and calculus.

BEE 685 Biological Engineering Analysis
Spring. 4 credits. Prerequisite: T&AM 310 or permission of instructor.

BEE 694 Graduate Special Topics in Agricultural and Biological Engineering
Fall, spring. 1–4 credits. S-U grades optional.

BEE 697 Graduate Individual Study in Agriculture and Biological Engineering
Fall, spring. 1–6 credits. Prerequisite: permission of instructor. S-U grades optional.

BEE 700 General Seminar
Fall. 1 credit. S-U grades only.

BEE 750 Orientation to Graduate Study
Fall. 1 credit. S-U grades only. Limited to newly joining graduate students.

BEE 754 Watershed Management
Spring. 2–3 credits. Prerequisite: graduate standing or permission of instructor.

BEE 771 Soil and Water Engineering Seminar
Fall, spring. 1–3 credits. Prerequisite: graduate status or permission of instructor. S-U grades optional.

BEE 781 Structures and Related Topics Seminar
Spring. 1 credit. Prerequisite: graduate status or permission of instructor. S-U grades only.

BEE 785 Biological Engineering Seminar
Spring. 1 credit. Prerequisite: graduate status or permission of instructor. S-U grades only.

BEE 800 Master's-Level Thesis Research
Fall, spring. 1–15 credits. Prerequisite: permission of adviser. S-U grades only.

BEE 900 Doctoral-Level Thesis Research
Fall, spring. 1–15 credits. Prerequisite: permission of adviser. S-U grades only.

CHEMICAL ENGINEERING

CHEME 112 Introduction to Chemical Engineering (also ENGRI 112)
Fall. 3 credits. Limited to freshmen. T. M. Duncan.
This is a course in the Introduction to Engineering series. For description, see ENGRI 112.

[CHEME 120 Introduction to Biomedical Engineering (also ENGRI 120)
Fall. 3 credits. Not offered 2002–2003.
This is a course in the Introduction to Engineering series. For description, see ENGRI 120.]

CHEME 219 Mass and Energy Balances (also ENGRD 219)
Fall. 3 credits. Corequisite: physical or organic chemistry or permission of instructor. K. H. Lee.
For description, see ENGRD 219.

CHEME 301 Nonresident Lectures
Spring. 1 credit. M. Ackley.
Lecturers from industry and from selected departments of the university provide information to assist students in their post-graduate plans.

CHEME 313 Chemical Engineering Thermodynamics
Fall. 4 credits. Corequisite: physical chemistry. F. A. Escobedo.
A study of the first and second laws and their consequences for chemical systems. Thermodynamic properties of pures fluids, solids, and mixtures; phase and chemical reaction equilibrium; heat effects in batch and flow processes; and power cycles and refrigeration.

CHEME 323 Fluid Mechanics
Fall. 3 credits. Prerequisites: CHEME 219 and engineering mathematics sequence. W. L. Olbricht.
Fundamentals of fluid mechanics. Macroscopic and microscopic balances. Applications to problems involving viscous flow.

CHEME 324 Heat and Mass Transfer
Spring. 3 credits. Prerequisite: CHEME 323. C. Cohen.
Fundamentals of heat and mass transfer. Macroscopic and microscopic balances. Applications to problems involving conduction, convection, and diffusion.

CHEME 332 Analysis of Separation Processes
Spring. 3 credits. Prerequisites: CHEME 313 and 323. Y. L. Joo.
Analysis of separation processes involving phase equilibria and mass transfer. Covers: phase equilibria; binary and multicomponent distillation; liquid-liquid extraction; gas absorption, absorption, membrane separations.

CHEME 372 Introduction to Process Dynamics and Control
Spring. 1 credit. Prerequisites: CHEME 313 and 323. D. L. Koch.
Modeling and analysis of the dynamics of chemical processes, Laplace transforms, block diagrams, feedback control systems, and stability analysis.

CHEME 390 Reaction Kinetics and Reactor Design
Spring. 3 credits. Prerequisites: CHEME 313 and 323. J. R. Engstrom.
A study of chemical reaction kinetics and principles of reactor design for chemical processes.

CHEME 391 Physical Chemistry II (also CHEM 391)
Spring. 4 credits. Limited to engineering students. T. M. Duncan.
For description, see CHEM 391.

CHEME 401 Molecular Principles of Biomedical Engineering
Fall. 3 credits. K. H. Lee.
Introduction to genomics, proteomics, bioinformatics, and computational biology with an emphasis on the engineering challenges for these areas. Cytoskeletal and motor proteins and their relationship to nano- and micro-machines and nanobiotechnology. Existing and emerging technologies and instrumentation critical to molecular-level analysis in Biomedical Engineering.

CHEME 402 Cellular Principles of Biomedical Engineering
Spring. 3 credits. D. Putnam.
Structural biomaterials: statistics and dynamics. Fluidics and the single cell. Cellular communication: a biomedical engineering viewpoint of the molecular basis of synaptic function of the nervous system; secretory processes. Building organisms: developmental biology from a cell biology point of view. The culture of cells and tissue as a biomedical engineering challenge.

CHEME 432 Chemical Engineering Laboratory
Fall. 4 credits. Prerequisites: CHEME 323, 324, 332, and 390. K. E. Ackley and staff.
Laboratory experiments in fluid dynamics, heat and mass transfer, kinetics, other operations. Correlation and interpretation of data. Technical report writing.

CHEME 462 Chemical Process Design
Spring. 4 credits. Prerequisite: CHEME 432. K. E. Ackley and staff.
A consideration of process and economic alternatives in selected chemical processes; design and assessment.

CHEME 470 Process Control Strategies
Spring. 3 credits. A. M. Center.
Introduction to how control concepts are represented, control valve sizing and selection, process control strategies, dynamic response of process systems as it relates to control loop tuning, statistical process control, advanced process control methods both for chemical and biological processes and programmable logic controllers and distributed control systems.

CHEME 472 Feedback Control Systems (also ECE 471 and M&AE 478)
Fall. 4 credits. Prerequisites: CHEME 372, ECE 301, M&AE 326, or permission of instructor. A. B. Anton and R. D'Andrea.
For description, see M&AE 478.

CHEME 480 Chemical Processing of Electronic Materials
Spring. 3 credits. A. B. Anton.
Introduction to chemical processing of semiconductor materials for the manufacture of microelectronic devices, with specific emphasis on thermodynamics, transport phenomena, and kinetics. Topics include semiconductor properties and behavior, microelectronic device operation, thermochemistry of deposition and etching reactions, vacuum transport, plasmas, PVD, oxidation, diffusion, CVD, and statistical process control.

CHEME 481 Biomedical Engineering
Spring. 3 credits. Prerequisite: CHEME 324 or equivalent or permission of instructor. W. L. Olbricht.
Special topics in biomedical engineering, including cell separations, blood flow, design of artificial devices, biomaterials, image analysis, biological transport phenomena, pharmacokinetics and drug delivery, biomedical transducers (ECG and pace makers), and analysis of physiological processes such as adhesion, mobility, secretion, and growth.

CHEME 484 Microchemical and Microfluidic Systems
Fall. 3 credits. Prerequisite: CHEME 390 or permission of instructor. J. R. Engstrom.
Principles of chemical kinetics, thermodynamics and transport phenomena applied to microchemical and microfluidic systems. Applications in distributed chemical production, portable power, micromixing, separations, and chemical and biological sensing and analysis. Fabrication approaches (contrasted with microelectronics), transport phenomena at small dimensions, modeling challenges, system integration, case studies. Group design project, including computational fluid dynamics (CFD) calculations, drafting an invention disclosure/patent application.

CHEME 490 Undergraduate Projects in Chemical Engineering
Fall, spring. Variable credit.
Research or studies on special problems in chemical engineering.

CHEME 491 Undergraduate Teaching in Chemical Engineering
Fall. 1 credit. T. M. Duncan and M. Ackley.
Methods of instruction in chemical engineering acquired through discussions with faculty and by assisting with the instruction of freshmen and sophomores.

CHEME 520 Chemical, Polymer, Biomedical, and Electronic Materials Processing
Fall, spring. 1–6 credits (1 credit per section).

520.1 An Overview of Chemical Processing
Spring. 1 credit. Meets first third of term. Limited to non-chemical engineers. T. M. Duncan.
An introduction to chemical engineering design and analysis-mathematical modeling, graphical methods and dynamic scaling. Open to nonchemical engineers only.

520.2 Introduction to Biomedical Engineering
Spring. 1 credit. Meets first third of term. W. L. Olbricht.
Meets concurrently with CHEME 481.

520.3 Introduction to Electronic Materials Processing
Spring. 1 credit. Meets first third of term. A. B. Anton.
Meets concurrently with CHEME 480.

520.4 Introduction to Polymer Processing
Spring. 1 credit. Meets final second of term. L. A. Archer.
Overview and simple quantitative analyses of several plastic processes with an emphasis on the role of rheology in polymer processing.

520.5 Chemical Engineering Processing Units and Equipment
Spring. 1 credit. Meets first third of term. K. E. Ackley and A. M. Center.
A hands-on survey of standard chemical processing equipment-structure and operation—with emphasis on trouble-shooting techniques.

520.6 Introduction to Petroleum Refining
Fall. 1 credit. Meets second third of term. A. M. Center.
The technical and business aspects of petroleum refining. Applications of chemical engineering principles for practical solutions to business needs.

520.7 Process Control Strategies
Spring. 1 credit. Meets first third of term. A. M. Center.
Meet concurrently with CHEME 470.

CHEME 562 Managing Chemical Process Design
Spring. 1 or 2 credits. Prerequisite: CHEME 462. K. E. Ackley.
Guidance and evaluation of chemical process designs developed by teams of chemical engineers.

[CHEME 564 Design of Chemical Reactors
Spring. 3 credits. Prerequisite: CHEME 390 or equivalent. Offered alternate years; not offered 2002–2003.
Design, scale-up, and optimization of chemical reactors with allowance for heat and mass transfer and nonideal flow patterns. Homework problems feature analysis of published data for gas-solid, gas-liquid, and three-phase reaction systems.]

CHEME 565 Design Project
Fall, spring. 3 or 6 credits. Required for students in the M.Eng. (Chemical) program.
Design study and economic evaluation of a chemical processing facility, alternative methods of manufacture, raw-material preparation, food processing, waste disposal, or some other aspect of chemical processing.

CHEME 572 Managing Business Development Solutions
Fall. 3 credits. Prerequisites: graduate standing; undergraduates must have permission of instructor. A. M. Center.
A case study approach introduces the typical fundamental factors driving a business venture, examines how to develop implementation strategies for the venture, and teaches the project management skills necessary to successfully implement the venture.

CHEME 590 Special Projects in Chemical Engineering
Fall, spring. Variable credit. Limited to graduate students.
Non-thesis research or studies on special problems in chemical engineering.

[CHEME 596 Systems on a Chip
Fall. 3 credits. Not offered 2002. P. Clancy.
Fundamentals of electronic chip fabrication processes for systems on a chip, the complexities of building devices on dissimilar substrates (e.g. Si on plastics), the creation of organic optoelectronic devices, and functional design integration issues. Applications to lab on a chip systems. Group design project required.]

CHEME 605 Fundamentals in Biomedical Engineering I (also ENGRG 605)
Fall. 1–4 credits (1 credit per section). Prerequisites: graduate standing in Engineering or Science; PHYS 213 and MATH 294 or equivalent. Undergraduates must have permission of instructor and have completed BEE 454, CHEME 481, or M&AE 465. S-U grades optional for students not majoring or minoring in biomedical engineering.
For description, see ENGRG 605.

CHEME 606 Fundamentals of Biomedical Engineering II (also ENGRG 606)
Spring. 1–4 credits. Prerequisits: graduate standing in engineering or science; PHYS 213 and MATH 294 or equivalent. Undergraduates must have permission of instructor. S-U grades optional for students not majoring or minoring in biomedical engineering. Coordinator: M. L. Shuler.
A series of one and two-credit modules on specialized topics.

CHEME 640 Polymeric Materials
Fall. 3 credits. C. Cohen.
Chemistry and physics of the formation and characterization of polymers. Principles of fabrication.

CHEME 643 Bioprocess Engineering
Fall. 3 credits. Prerequisite: CHEME 390 or permission of instructor. No prior background in the biological sciences required. M. L. Shuler.
A discussion of principles involved in using microorganisms, tissue cultures, and enzymes for processing. Application to food, fermentation, and pharmaceutical industries and to biological waste treatment.

CHEME 644 Aerosols and Colloids
Fall. 3 credits. D. Koch.
Dynamics of micro- and nano-particles, which contain many molecules but are small enough that molecular effects are important. Topics include the formation and growth of particles; their transport, theological and phase behaviors; and their role in technologies including paints, foods, health-care products, drug delivery, composite materials, and air pollution control.

[CHEME 656 Separations Using Membranes or Porous Solids
Spring. 3 credits. Prerequisites: CHEME 324 and 332. Offered alternate years; not offered 2002–2003.
Diffusion of small molecules in gases, liquids, and solids. Membrane separation processes including gas separation, pervaporation, reverse osmosis, and ultrafiltration. Purification of gases and liquids by adsorption, ion exchange, and chromatography.]

CHEME 661 Air Pollution Control
Spring. 3 credits. P. H. Stern.
Origin of air pollutants, U.S. emission standards, dispersion equations. Design of equipment for removal of particulate and gaseous pollutants formed in combustion and chemical processing.

CHEME 675 Synthetic Polymer Chemistry (also MS&E 622 and CHEM 671)
Fall. 4 credits. Prerequisites: CHEM 359–360 or equivalent or permission of instructor.
For description, see CHEM 671.

CHEME 711 Advanced Chemical Engineering Thermodynamics
Fall. 3 credits. Prerequisite: CHEME 313 or equivalent. P. Clancy.
Postulatory approach to thermodynamics. Legendre transformations. Equilibrium and stability of general thermodynamic systems. Applications of thermodynamic methods to advanced problems in chemical engineering. Introduction to statistical mechanical ensembles, phase transitions, Monte Carlo methods, and theory of liquids.

CHEME 713 Chemical Kinetics and Dynamics
Spring. 3 credits. Prerequisite: CHEME 390 or equivalent. F. Escobedo.
Topics include: microscopic and macroscopic viewpoints; connections between phenomenological chemical kinetics and molecular reaction dynamics; reaction cross sections, potential energy surfaces, and dynamics of bimolecular collisions; molecular beam scattering; transition state theory. Unimolecular reaction dynamics; complex chemically reacting systems: reactor stability, multiple steady states, oscillations, and bifurcation; reactions in heterogeneous media; and free-radical mechanisms in combustion and pyrolysis.

CHEME 731 Advanced Fluid Mechanics and Heat Transfer
Fall. 3 credits. Prerequisites: CHEME 323 and 324 or equivalent.
Topics include: derivation of the equations of motion for Newtonian fluids; low Reynolds number fluid dynamics, lubrication theory, inviscid fluid dynamics; boundary layer theory; and convective and conductive heat transfer.

CHEME 732 Diffusion and Mass Transfer
Spring. 2 credits. Prerequisite: CHEME 731 or equivalent. L. A. Archer.
Conservation equations in multicomponent systems, irreversible thermodynamics, dispersion, and Brownian diffusion. Mass transfer for convective diffusion in liquids. Application to a variety of problems such as coagulation of aerosols, diffusion through films and membranes, liquid-liquid extraction, chemical vapor deposition, polymer rheology and diffusion, and reaction-diffusion systems.

CHEME 741 Selected Topics in Biochemical Engineering
Fall, spring. 1 credit (may be repeated for credit). Prerequisite: permission of instructor. K. H. Lee, and M. L. Shuler.
Discussion of current topics and research in biochemical engineering for graduate students.

CHEME 745 Physical Polymer Science I
Fall. 3 credits. Corequisite: CHEME 711 or equivalent. Offered alternate years; not offered 2002–2003. C. Cohen.
Covers thermodynamic properties of dilute, semidilute, and concentrated solutions from both classical and scaling approaches. Also covers characterization techniques of dilute solutions: osmometry, light scattering, viscometry, and sedimentation. Covers rubber elasticity; mechanical and thermodynamic properties of gels. Includes discussion of polymer melts: equations of state and glass transition phenomena.

CHEME 751 Mathematical Methods of Chemical Engineering Analysis
Fall. 4 credits. D. L. Koch.
Application of advanced mathematical techniques to chemical engineering analysis. Mathematical modeling, scaling, regular and singular perturbations, multiple scales, asymptotic analysis, linear and nonlinear ordinary and partial differential equations, statistics, data analysis, and curve fitting.

CHEME 753 Analysis of Nonlinear Systems: Stability, Bifurcation, and Continuation
Fall. 3 credits. Prerequisite: CHEME 751 or equivalent. Offered alternate years; not offered 2002–2003. P. H. Steen.
Topics covered include: elements of stability and bifurcation theory; branch-following techniques; stability of discrete and continuous systems; and application to elasticity, reaction-diffusion, and hydrodynamic systems using software for continuation problems.

CHEME 790 Seminar
Fall, spring. 1 credit each term.
General chemical engineering seminar required of all graduate students in the field of chemical engineering.

CHEME 792 Principles and Practices of Graduate Research
Fall, spring. 1 credit. T. M. Duncan and staff.
A colloquium/discussion group series for first-year graduate students. Topics include the culture and responsibilities of graduate research and the professional community; the mechanics of conducting research (experimental design, data analysis, serendipity in research, avoiding self-deception), documenting research (lab notebooks, computer files), and reporting research (writing a technical paper and oral presentations).

CHEME 890 Thesis Research
Fall, spring. Variable credit.
Thesis research for the M.S. degree in chemical engineering.

CHEME 990 Thesis Research
Fall, spring. Variable credit.
Thesis research for the Ph.D. degree in chemical engineering.

CIVIL AND ENVIRONMENTAL ENGINEERING

Courses in the School of Civil and Environmental Engineering are offered in three broad mission areas: Civil Infrastructure, Environment, and Systems Engineering and Information Technology. Within each mission area are several areas of specialization. The following are the course numbers and titles listed by specialization within each mission area. Some courses are listed in two or more mission areas because the course content is relevant to multiple areas. The school also offers a number of general courses that are not unique to one mission area. Full course descriptions follow in the subsequent section and are listed in numerical order.

General

CEE 113 Solving Environmental Problems for Urban Regions (also ENGRI 113) (F,3cr.)

CEE 116 Modern Structural Systems and Materials (also ENGRI 116) (F,3cr.)

CEE 241 Engineering Computation (also ENGRD 241) (F,S,3cr.)

CEE 304 Uncertainty Analysis in Engineering (F,4cr.)

CEE 308 Introduction to CADD (F,S,1cr.)

CEE 309 Special Topics in Civil and Environmental Engineering (F,S,var.)

CEE 323 Engineering Economics and Management (also ENGRG 323) (S,Su,3cr.)

CEE 400 Senior Honors Thesis (F,S,var.)

CEE 401 Undergraduate Engineering Teaching in CEE (F,S,var.)

Civil Infrastructure

See also: CEE 116, CEE 241, CEE 304, CEE 308, CEE 503, and CEE 595

Geotechnical Engineering

CEE 341 Introduction to Geotechnical Engineering and Analysis (S,4cr.)

CEE 501/502 Design Project in Geotech/ Structures (F,S,3cr.)

CEE 602 Civil Infrastructure Seminar (F,1cr.)

CEE 640 Foundation Engineering (F,3cr.)

CEE 641 Retaining Structures and Slopes (S,3cr.)

CEE 644 Environmental Applications of Geotechnical Engineering (S,3cr.)

CEE 649 Special Topics in Geotechnical Engineering (F,S,var.)

CEE 740 Engineering Behavior of Soils (F,3cr.)

CEE 741 Rock Engineering (S,3cr.)

CEE 744 Advanced Foundation Engineering (S,2cr.)

CEE 745 Soil Dynamics (S,3cr.)

CEE 746 Embankment Dam Engineering (S,2cr.)

CEE 749 Research in Geotechnical Engineering (F,S, var.)

CEE 840 Thesis—Geotechnical Engineering (F,S,var.)

Structural Engineering

CEE 116 Modern Structural Systems and Materials (F,3cr.)

CEE 371 Modeling of Structural Systems (S,4cr.)

CEE 376 Physical and Computational Material Simulation

CEE 472 Fundamentals of Structural Mechanics (F,3cr.)

CEE 473 Design of Concrete Structures (S,4cr.)

CEE 474 Design of Steel Structures (S,4cr.)

CEE 475 Introduction to Composite Materials (S,4cr.)

CEE 479 Collaborative Distance Design of Structural Systems

CEE 501/502 Design Project in Geotech/ Structures (F,S,3cr.)

CEE 602 Civil Infrastructure Seminar (F,S,1cr.)

CEE 671 Random Vibration (F,3cr.)

CEE 673 Engineering Analysis (F,3cr.)

CEE 674 Finite Element Modeling of Civil Infrastructure (S,3cr.)

CEE 675 Concrete Materials and Construction (S,3cr.)

CEE 676 Finite Element Analysis for Mechanical, Structural, and Aerospace Applications (S,3cr.)

CEE 677 Stochastic Problems in Science and Engineering (F,3cr.)

CEE 678 Structural Dynamics and Earthquake Engineering (S,3cr.)

CEE 770 Engineering Fracture Mechanics (F,3cr.)

CEE 774 Advanced Structural Concrete (F,3cr.)

CEE 775 Structural Concrete Systems (S,3cr.)

CEE 776 Advanced Design of Metal Structures (F,3cr.)

CEE 777 Advanced Behavior of Metal Structures (S,3cr.)

CEE 778 Fundamentals of Structural Mechanics (S,4cr.)

CEE 783 Civil and Environmental Engineering Materials Project (F,S,var.)

CEE 785 Research in Structural Engineering (F,S,var.)

CEE 786 Special Topics in Structural Engineering (F,S,var.)

CEE 880 Thesis—Structural Engineering (F,S,var.)

Environment

See also CEE 113, CEE 241, and CEE 304

Environmental Engineering

CEE 113 Solving Environmental Problems for Urban Regions (F,3cr.)

CEE 351 Environmental Quality Engineering (S,3cr.)

CEE 352 Water Supply Engineering (F,3cr.)

CEE 451 Microbiology for Environmental Engineering (F,3cr.)

CEE 453 Laboratory Research in Environmental Engineering (S,3cr.)

CEE 501/502 Design Project in Environmental Engineering (F,S,3cr.)

CEE 601 Water Resources and Environmental Engineering Seminar (F,1cr.)

CEE 653 Water Chemistry for Environmental Engineering (F,3cr.)

CEE 654 Aquatic Chemistry (S,3cr.)

CEE 655 Transport, Mixing, and Transformation in the Environment (F,3cr.)

CEE 659 Environmental Quality Engineering Seminar (S,1cr.)

CEE 750 Research in Environmental Engineering (F,S,var.)

CEE 755 Physical/Chemical Processes (F,3cr.)

CEE 756 Biological Processes (S,3cr.)

CEE 757 Physical/Chemical Processes Laboratory (F,2cr.)

CEE 758 Biological Processes Laboratory (S,2cr.)

CEE 759 Special Topics in Environmental Engineering (F,S,var.)

CEE 850 Thesis—Environmental Engineering (F,S,var.)

Environmental Systems

See Systems Engineering and Information Technology mission areas for a listing of courses in Environmental and Public Systems.

Environmental Fluid Mechanics and Hydrology

CEE 331 Fluid Mechanics (F,Su,4cr.)

CEE 332 Hydraulic Engineering (S,4cr.)

CEE 431 Geohydrology (also GEOL 445 and BEE 471) (F,3cr.)

CEE 432 Hydrology (S,3cr.)

CEE 435 Coastal Engineering (S,4cr.)

CEE 436 Case Studies in Environmental Fluid Mechanics (S,4cr.)

CEE 437 Experimental Methods in Fluid Dynamics (S,3cr.)

CEE 501/502 Design Project in Fluid Mechanics and Hydrology (F,S,3cr.)

CEE 601 Water Resources and Environmental Engineering Seminar (F,1cr.)

CEE 630 Advanced Fluid Mechanics (F,3cr.)

CEE 631 Flow and Contaminant Transport Modeling in Groundwater (S,3cr.)

CEE 632 Hydrology (S,3cr.)

CEE 633 Flow in Porous Media and Groundwater (F,3cr.)

CEE 634 Boundary Layer Meteorology (F,3cr.)

CEE 635 Small and Finite Amplitude Water Waves (S,3cr.)

CEE 636 Environmental Fluid Mechanics (S,3cr.)

CEE 637 Experimental Methods in Fluid Dynamics (S,4cr.)

CEE 638 Hydraulics Seminar (S,1cr.)

CEE 639 Special Topics in Hydraulics (F,S,var.)

CEE 655 Transport, Mixing, and Transformation in the Environment (F,3cr.)

CEE 732 Computational Hydraulics (F,3cr.)

CEE 735 Research in Hydraulics (F,S,var.)

CEE 830 Thesis—Fluid Mechanics and Hydrology (F,S,var.)

Systems Engineering and Information Technology

See also CEE 113, CEE 241, and CEE 304

Engineering Management

CEE 490 Management Practice in Project Engineering (S,3cr.)

CEE 590 Project Management (F,S,4cr.)

CEE 591 Engineering Management Project (F,3cr.)

CEE 592 Engineering Management Project (S,3cr.)

CEE 593 Engineering Management Methods I: Data, Information, and Modeling (F,3cr.)

CEE 594 Economic Methods for Engineering and Management (S,4cr.)

CEE 595 Construction Planning and Operations (F,3cr.)

CEE 596 Current Topics in Construction Management (S,3cr.)

There was a printing error in this volume

Pages 225-256 were not included

There were two sets of pages 257-288 instead

Only one set of pages 257-288

is included here

OR&IE 597 Systems Engineering Project
Fall; R grade only; spring, 8 credits. For M.Eng. students.
For M. Eng. Students enrolled in the Systems Engineering Option. A substantial, group-based design project that has a strong systems design component. The project must be approved by an ASE 1 instructor before the student enrolls in the course. (The following projects are pre-approved: FSAE, HEV, Robocup, Brain.) A formal report is required.

OR&IE 598 Master of Engineering Manufacturing Project
Fall. R grade only; spring, 5 credits. For M.Eng. students.
Project course for M.Eng. students enrolled in the Manufacturing Option coordinated by the Center for Manufacturing Enterprise.

OR&IE 599 Project
Fall. R grade only; spring, 5 credits. For M.Eng. students.
Identification, analysis, design, and evaluation of feasible solutions to some applied problem in the OR&IE field. A formal report and oral defense of the approach and solution are required.

[OR&IE 625 Scheduling Theory
Fall. 3 credits. Not offered 2002–2003.
Scheduling and sequencing problems, including single-machine problems, parallel-machine scheduling, and shop scheduling. The emphasis is on the design and analysis of polynomial time optimization and approximation algorithms and on related complexity issues.]

[OR&IE 626 Advanced Production and Inventory Planning
Spring. 3 credits. R. Roundy.
Introduction to a variety of production and inventory control planning problems, the development of mathematical models corresponding to these problems, and a study of approaches for finding solutions.]

OR&IE 630 Mathematical Programming I
Fall. 4 credits. Prerequisites: advanced calculus and elementary linear algebra. J. Renegar.
A rigorous treatment of the theory and computational techniques of linear programming and its extensions, including: formulation, duality theory, algorithms; sensitivity analysis; network flow problems and algorithms; theory of polyhedral convex sets, systems of linear equations and inequalities, Farkas' Lemma; and exploiting special structure in the simplex method, and computational implementation.

OR&IE 631 Mathematical Programming II
Spring. 4 credits. Prerequisite: OR&IE 630. M. Todd.
A continuation of OR&IE 630. Introduction to nonlinear programming, interior-point methods for linear programming, complexity theory, and integer programming. Includes some discussion of dynamic programming and elementary polyhedral theory.

OR&IE 632 Nonlinear Programming
Fall. 3 credits. Prerequisite: OR&IE 630. M. Todd.
Necessary and sufficient conditions for unconstrained and constrained optima. Topics include the duality theory, computational methods for unconstrained problems (e.g., quasi-Newton algorithms), linearly constrained problems (e.g., active set methods), and nonlinearly constrained problems (e.g., successive quadratic programming, penalty, and barrier methods).

[OR&IE 633 Graph Theory and Network Flows
Spring. 3 credits. Prerequisite: permission of instructor. Not offered 2002–2003.
Topics covered include: directed and undirected graphs; bipartite graphs; hamilton cycles and Euler tours; connectedness, matching, and coloring; flows in capacity-constrained networks; and maximum flow and minimum cost flow problems.]

OR&IE 634 Combinatorial Optimization
Spring. 3 credits. R. Bland.
Topics in combinatorics, graphs, and networks, including matching, matroids, polyhedral combinatorics, and optimization algorithms.

[OR&IE 635 Interior-Point Methods for Mathematical Programming
Spring. 3 credits. Prerequisites: MATH 411 and OR&IE 630, or permission of instructor. Not offered 2002–2003.
Interior-point methods for linear, quadratic, and semidefinite programming and, more generally, for convex programming. Discussion of the basic ingredients—barrier functions, central paths, and potential functions—that go into the construction of polynomial-time algorithms, and various ways of combining them. Emphasis on recent mathematical theory and the most modern viewpoints.]

OR&IE 636 Integer Programming
Fall. 3 credits. Prerequisite: OR&IE 630. L. Trotter.
Topics covered include: discrete optimization; linear programming in which the variables must assume integral values; theory, algorithms, and applications; and cutting-plane and enumerative methods, with additional topics drawn from recent research in this area.

[OR&IE 637 Semidefinite Programming
Spring; weeks 8–14. 2 credits. Pre- or corequisite: OR&IE 635. Not offered 2002–2003.
Course covers: linear optimization over the cone of positive semidefinite symmetric matrices; applications to control theory, eigenvalue optimization, and strong relaxations of combinatorial optimization problems; duality; computational methods, particularly interior-point algorithms.]

[OR&IE 639 Polyhedral Convexity
Spring. 3 credits. Prerequisite: basic knowledge of linear algebra. Not offered 2002–2003.
A comprehensive introduction to the geometry and combinatorics of polyhedral convex sets. Also, linear inequalities, supporting and separating hyperplanes; polarity; convex hulls, facets, and vertices; face lattices; convex cones and polytopes; minkowski sums; gale transforms; simplicial and polyhedral subdivision; and applications to linear programming, combinatorial optimization, and computational geometry.]

OR&IE 650 Applied Stochastic Processes
Fall. 4 credits. Prerequisite: a 1-semester calculus-based probability course. S. Henderson.
An introduction to stochastic processes that presents the basic theory together with a variety of applications. Topics include: Markov processes, renewal theory, random walks, branching processes, Brownian motion, stationary processes, martingales, and point processes.

OR&IE 651 Probability
Spring. 4 credits. Prerequisite: real analysis at the level of MATH 413 and a previous 1-semester course in calculus-based probability. Staff.
Course covers: sample spaces, events, sigma fields, probability measures, set induction, independence, random variables, expectation, review of important distributions and transformation techniques, convergence concepts, laws of large numbers and asymptotic normality, and conditioning.

[OR&IE 662 Advanced Stochastic Processes
Fall. 3 credits. Prerequisite: OR&IE 651 or equivalent. Not offered 2002–2003.
Course topics include: Brownian motion, martingales, Markov processes, and topics selected from: diffusions, stationary processes, point processes, weak convergence for stochastic processes and applications to diffusion approximations, Lévy processes, regenerative phenomena, random walks, and stochastic integrals.]

OR&IE 670 Statistical Principles
Fall. 4 credits. Corequisite: OR&IE 650 or equivalent. B. Turnull.
Topics include: review of distribution theory of special interest in statistics: normal, chi-square, binomial, Poisson, t, and F; introduction to statistical decision theory; sufficient statistics; theory of minimum variance unbiased point estimation; maximum likelihood and Bayes estimation; basic principles of hypothesis testing, including Neyman-Pearson Lemma and likelihood ratio principle; confidence interval construction; and introduction to linear models

[OR&IE 671 Intermediate Applied Statistics
Spring. 3 credits. Prerequisite: OR&IE 670 or equivalent. Not offered 2002–2003.
Course topics include: statistical inference based on the general linear model; least-squares estimators and their optimality properties; likelihood ratio tests and corresponding confidence regions; and simultaneous inference. Applications in regression analysis and ANOVA models. Covers variance components and mixed models. Use of the computer as a tool for statistics is stressed.]

[OR&IE 674 Statistical Learning Theory for Data Mining
Fall. 3 credits. Prerequisites: Probability at the level of OR&IE 651, and statistical at the level of OR&IE 670. W. Jiang.
This course will provide a thorough grounding in probabilistic and computational methods for statistical data mining. We intend to cover a subset of the following topics from supervised and unsupervised data mining: The framework of learning. Performance measures and model selection. Methodology, theoretical properties and computing algorithms used in parametric and nonparametric methods for regression and classification. Frequentist and Bayesian methods.]

OR&IE 677 Sequential Methods in Statistics
Spring. 3 credits. S-U grades only. B. Turnbull.
The statistical theory of sequential design and analysis of experiments has many applications; including monitoring data from clinical trials in medical studies and quality control in manufacturing operations. Topics in this course include: classical sequential hypothesis tests, Wald's SPRT, stopping rules, Kiefer-Weiss test, optimality, group sequential methods, estimation, repeated confidence intervals, stochastic curtailment, adaptive designs, and bayesian and decision theoretic approaches.

[**OR&IE 680 Simulation**
Fall. 4 credits. Prerequisite: computing experience and OR&IE 650 or equivalent, or permission of instructor. Not offered 2002–2003.
Introduction to Monte Carlo and discrete-event simulation. Emphasis on underlying theory. Random variate generation, input and output analysis, variance reduction, selection of current research topics.]

OR&IE 728–729 Selected Topics in Applied Operations Research
Fall, spring. Credit TBA.
Current research topics dealing with applications of operations research.

OR&IE 738–739 Selected Topics in Mathematical Programming
Fall, spring. Credit TBA.
Current research topics in mathematical programming.

OR&IE 768–769 Selected Topics in Applied Probability
Fall, spring. Credit TBA.
Topics are chosen from current literature and research areas of the staff.

OR&IE 778–779 Selected Topics in Applied Statistics
Fall, spring. Credits TBA.
Topics chosen from current literature and research of the staff.

OR&IE 790 Special Investigations
Fall, spring. Credit TBA.
For individuals or small groups. Study of special topics or problems.

OR&IE 799 Thesis Research
Fall, spring. Credit TBA.
For individuals doing thesis research for master's or doctoral degrees.

OR&IE 891 Operations Research Graduate Colloquium
Fall, spring. 1 credit. Staff.
A weekly 1-1/2 hour meeting devoted to presentations by distinguished visitors, by faculty members, and by advanced graduate students on topics of current research in the field of operations research.

OR&IE 893–894 Enterprise Engineering Colloquium (also M&AE 594)
893, fall; 894, spring. 1 credit (usually S-U) each term.
A weekly meeting for Master of Engineering students. Discussion with industry speakers and faculty members on the uses of engineering in the economic design, manufacturing, marketing, and distribution and goods and services.

THEORETICAL AND APPLIED MECHANICS

Basics in Engineering Mathematics and Mechanics

T&AM 118 Design Integration: A Portable CD Player (also ENGRI 118 and MS&E 118)
Spring. 3 credits.
This is a course in the Introduction to Engineering series. For description, see ENGRI 118.

T&AM 202 Mechanics of Solids (also ENGRD 202)
Fall, spring. 3 credits Prerequisite: PHYS 112, coregistration in MATH 293 or permission of instructor.
For description, see ENGRD 202.

T&AM 203 Dynamics (also ENGRD 203)
Fall, spring. 3 credits. Prerequisite: T&AM 202, coregistration in MATH 294, or permission of instructor.
For description, see ENGRD 203.

Engineering Mathematics

T&AM 190 Calculus for Engineers (also MATH 190)
Fall. 4 credits. Prerequisite: 3 years of high school mathematics, including trigonometry and logarithms.
For description, see MATH 190.

T&AM 191 Calculus for Engineers (also MATH 191)
Fall. 4 credits. Prerequisite: 3 years of high school mathematics, including trigonometry.
For description, see MATH 191.

T&AM 192 Calculus for Engineers (also MATH 192)
Fall, spring, or summer. 4 credits. Prerequisite: MATH/T&AM 191.
For description, see MATH 192.

T&AM 293 Engineering Mathematics (also MATH 293)
Fall, spring. 4 credits. Prerequisite: MATH/T&AM 192 plus a knowledge of computer programming equivalent to that taught in COM S 100.
For description, see MATH 293.

T&AM 294 Engineering Mathematics (also MATH 294)
Fall, spring. 4 credits. Prerequisite: MATH/T&AM 293.
For description, see MATH 294.

T&AM 310 Advanced Engineering Analysis I
Fall, spring. 3 credits. Prerequisite: MATH/T&AM 294 or equivalent.
Course covers: initial value, boundary value, and eigenvalue problems in linear ordinary differential equations. Also covers: special functions, linear partial differential equations. This is an introduction to probability and statistics. Use of computers to solve problems is emphasized.

T&AM 311/511 Advanced Engineering Analysis II
Spring. 3 credits. Prerequisite: MATH/T&AM 294 or equivalent (T&AM 311 can be taken without T&AM 310).
Mathematical modeling of physical and biological systems. Examples range from molecular diffusion, bacteria swimmers, chemotaxis, and physiological flows, to bird flight. The mathematics necessary to understand these phenomena is discussed in depth. They include probability theory, PDEs, stability analysis, complex variable analysis, and numerical analysis. Students from all fields are encouraged to take the course.

T&AM 610 Methods of Applied Mathematics I
Fall. 3 credits. Intended for beginning graduate students in engineering and science. An intensive course, requiring more time than is normally available to undergraduates (see T&AM 310–311) but open to exceptional undergraduates with permission of instructor.
Emphasis is on applications. Course covers: linear algebra, calculus of several variables, vector analysis, series, ordinary differential equations, and complex variables.

T&AM 611 Methods of Applied Mathematics II
Spring. 3 credits. Prerequisite: T&AM 610 or equivalent.
Emphasis is on applications. Course covers: partial differential equations, transform techniques, tensor analysis, calculus of variations.

T&AM 612 Methods of Applied Mathematics III
Spring. 3 credits. Prerequisite: T&AM 610 and 611 or equivalent.
Course topics include: integral transform, methods, Wiener-Hopf technique, solutions of integral equations and partial differential equations. Problems are drawn from electromagnetics, elasticity, fluid mechanics, heat transfer, and acoustics.

T&AM 613 Methods of Applied Mathematics IV
Spring. 3 credits. Prerequisite: T&AM 610 and 611 or equivalent.
Topics include asymptotic behavior of solutions of linear and nonlinear ODE (e.g., the WKB boundry layer and multiple-scale methods) and symptotic expansion of integrals (method of steepest descent, stationary phase and Laplace methods). Also covers regular and singular perturbation methods for PDE (e.g., method of composite expansions). Other topics (depending on instructor) may include: normal forms, center manifolds, Liapunov-Schmidt reductors, and Stokes phenomenon. The course may also include computer exercises at the option of the instructor.

[**T&AM 614 Methods of Applied Math V**
Spring. 3 credits. Prerequisites: T&AM 610 plus T&AM 611 or equivalent. Not offered 2002–2003.]

T&AM 617 Advanced Mathematical Modeling
Spring. 3 credits. Offered alternate years.

Continuum Mechanics

T&AM 455 Introduction to Composite Materials (also CEE 475, M&AE 455 and MS&E 555)
Spring. 4 credits.
Course topics include: introduction to composite materials; varieties and properties of fiber reinforcements and matrix materials;

micromechanics of stiffness and stress transfer in discontinuous fiber/matrix arrays; orthotropic elasticity as applied to parallel fibers in a matrix and lamina; theory of stiffness (tension, bending, torsion) and failure of laminates and composite plates including computer software for design; and manufacturing methods and applications for composites. There is a group component design and manufacturing paper required, and a group laboratory on laminated component fabrication.

T&AM 591 Master of Engineering Design Project I
Fall. 3–6 credits.
M. Eng. (Mechanics) project related to the mechanics of advanced composites and structures.

T&AM 592 Master of Engineering Design Project II
Spring. 5–15 credits.
M. Eng. (Mechanics) project related to the mechanics of advanced composites and structures.

T&AM 655 Composite Materials (also M&AE 655 and MS&E 655)
Spring. 4 credits.
Taught jointly with T&AM 455 using same lecture material, but also includes more advanced material and homeworks through additional lectures. Additional material includes: shear-lag models of stress transfer around arrays of fiber breaks including viscoelastic effects, statistical theories of composite strength and failure; stress distributions around holes and cuts in composite laminates; and compressive strength of composites. Laboratory on effects of holes and notches in composites.

T&AM 663 Solid Mechanics I
Fall. 4 credits.
Rigorous introduction to solid mechanics emphasizing: linear elasticity: tensors; deformations, rotations and strains; balance principles; stress; small-strain theory; linear elasticity, anisotropic and isotropic; basic theorems of elastostatics; and boundary-value problems, e.g. plates, St. Venant's solutions.

T&AM 664 Solid Mechanics II
Spring. 4 credits. Prerequisites: MATH 610 and T&AM 663, or equivalent.
Preparation for advanced courses in solid mechanics. Topics include: singular solutions in linear elasticity; plane stress, plane strain, anti-plane shear, airy stress functions; linear viscoelasticity; cracks and dislocations; classical plasticity; thermoelasticity; and three-dimensional elasticity.

T&AM 666 Finite Element Analysis (also M&AE 680 and CEE 772)
Spring. 3 credits. Prerequisites: T&AM 663 or equivalent.
For description, see M&AE 680.

T&AM 751 Continuum Mechanics and Thermodynamics
Fall. 3 credits. Prerequisites: T&AM 610 and 611; and 663 and 664 or equivalents.
Course topics include: kinematics; conservation laws; the entropy inequality; constitutive relations: frame indifference, material symmetry; and finite elasticity, rate-dependent materials, and materials with internal state variables.

T&AM 752 Nonlinear Elasticity
Spring. 3 credits. Prerequisites: T&AM 610, 611, and 751 or equivalents. Offered alternate years.
Review of governing equations. Topics include: linearization and stability; constitutive inequalities; exact solution of special problems; nonlinear string and rod theories; phase transformations and crystal defects.

T&AM 753 Fracture
Fall. 3 credits. Prerequisites: T&AM 610 or 611; and 663 and 664 or equivalents. Offered alternate years.
Course covers: fundamentals of linear elastic fracture mechanics: K, small-scale yielding, solutions of elastic crack problems, energy concepts, J-integral. Also covers: nonlinear, rate-independent, small-deformation, fracture mechanics: plastic fracture, J-integral, small-scale yielding, fields for stationary and growing cracks; failure mechanisms of polymers, ceramics, composites, and metals: void growth, load transfer between fibers, crazing; fracture testing; fatigue fracture; computation of stress intensity factors; and plate theory and fracture.

[T&AM 757 Inelasticity
Spring. 3 credits. Prerequisites: T&AM 610 and 611; and 663 and 664 or equivalents. Offered alternate years. Not offered 2002–2003.
Course covers: plasticity: dislocation slip systems; early experimental observations; general principles; limit analysis; and solution of boundary-value problems, plastic waves, one- and three-dimensional. Also covers viscoelasticity: general principles, solution of boundary-value problems.]

[T&AM 759 Boundary Element Methods
Fall. 4 credits. Prerequisites: T&AM 610 and 611; and 633 and 644 or equivalents. Offered alternate years. Not offered 2002–2003.
Introduction to boundary element methods. Solutions for potential theory, linear elasticity, diffusion, material and/or geometric nonlinearities. Modern developments: hypersingular integrals, the boundary contour methods, sensitivity analysis.]

Dynamics and Space Mechanics

T&AM 570 Intermediate Dynamics
Fall. 3 credits.
Course topics include: Newtonian mechanics; motion in rotating coordinate systems; introduction to analytical mechanics; virtual work, Langrangian mechanics; Hamilton's principle; small vibration and stability theory. Newtonian-Eulerian mechanics of rigid bodies; and gyroscopes.

T&AM 578 Nonlinear Dynamics and Chaos
Fall. 3 credits. Prerequisite: MATH/T&AM 293 or equivalent.
Introduction to nonlinear dynamics, with applications to physics, engineering, biology, and chemistry. Emphasizes analytical methods, concrete examples, and geometric thinking. Topics: one-dimensional systems; bifurcations; phase plane; nonlinear oscillators; and Lorenz equations, chaos, strange attractors, fractals, iterated mappings, period doubling, renormalization.

T&AM 671 Hamiltonian Dynamics
Spring. 3 credits. Prerequisite: T&AM 570 or equivalent. Offered alternate years.
Course topics include: review of Lagrangian mechanics, Kane's equations; Hamilton's principle, the principle of least action, and related topics from the calculus of variations; Hamilton's canonical equations; approximate methods for two-degrees-of-freedom systems (Lie transforms); canonical transformations and Hamilton-Jacobi theory; KAM theory; and Melnikov's method.

T&AM 672 Celestial Mechanics (also ASTRO 579)
Spring. 3 credits. Offered alternate years.
Course topics include: description of orbits; 2-body, 3-body, and n-body problems; Hill curves, libration points and their stability; capture problems; osculating orbital elements, perturbation equations; effects of gravitational potentials, atmospheric drag, and solar radiation forces on satellite orbits; and secular perturbations, resonances, mechanics of planetary rings.

[T&AM 673 Mechanics of the Solar System (also ASTRO 571)
Spring. 3 credits. Prerequisite: an advanced undergraduate course in dynamics. Offered alternate years; not offered 2002–2003.
Course topics include: gravitational potentials, planetary gravity fields; free and forced rotations; Chandler wobble, polar wander, and damping of nutation; equilibrium tidal theory, tidal heating; orbital evolution of natural satellites, resonances, spin-orbit coupling, Cassini states; long-term variations in planetary orbits; dust dynamics; dynamics of ring systems; and physics of interiors, seismic waves, free oscillations. Illustrative examples are drawn from contemporary research.]

T&AM 675 Nonlinear Vibrations
Spring. 3 credits. Prerequisite: T&AM 578 or equivalent. Offered alternate years.
Quantitative analysis of weakly nonlinear systems in free and forced vibrations, perturbation methods, averaging method. Applications to problems in mechanics, physics, and biology. Additional topics may include Hopf bifurcation, Invariant manifolds, coupled oscillators, vibrations in continuous media, normal forms, and exploitation of symmetry.

[T&AM 678 Complex Systems
Spring. 3 credits. Prerequisites: T&AM 578 or equivalent. Offered alternate years; not offered 2002–2003.
Complex systems in physics, biology, engineering, economics, and the Internet. Topics: power laws, percolation, phase transitions, scaling, and renormalization. Self-organized criticality; neural, cardiac, genetic, power grid; and financial networks. Stochastic spatial models. Evolution on rugged landscapes.]

T&AM 776 Applied Dynamical Systems (also MATH 717)
For description, see MATH 717.

Special Courses, Projects, and Thesis Research

T&AM 491–492 Project in Engineering Science
Fall, 491; spring, 492. 1–4 credits, as arranged.
Projects for undergraduates under the guidance of a faculty member.

T&AM 796–800 Topics in Theoretical and Applied Mechanics
Fall, spring. 1–3 credits, as arranged.
Special lectures or seminars on subjects of current interest. Topics are announced when the course is offered.

T&AM 890 Master's Degree Research in Theoretical and Applied Mechanics
Fall, spring. 1–15 credits, as arranged. S-U grades optional.
Thesis or independent research at the M.S. level on a subject of theoretical and applied mechanics. Research is under the guidance of a faculty member.

T&AM 990 Doctoral Research in Theoretical and Applied Mechanics
Fall, spring. 1–15 credits, as arranged. S-U grades optional.
Thesis or independent research at the Ph.D. level on a subject of theoretical and applied mechanics. Research is under the guidance of a faculty member.

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